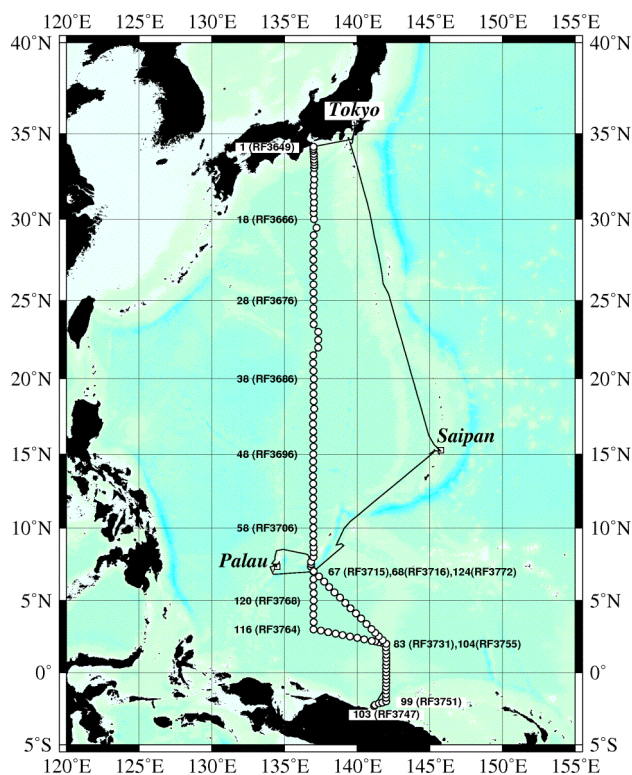


CRUISE REPORT: P09

(Updated FEB 2012)



HIGHLIGHTS

CRUISE SUMMARY INFORMATION

WOCE Section Designation	P09 (RF10-05)	
Expedition designation (ExpoCodes)	49UP20100706	
Chief Scientists	Toshiya Nakano	
Dates	2010 JUL 06 - 2010 AUG 22	
Ship	<i>R/V Ryofu Maru</i>	
Ports of call	Tokyo - Palau - Saipan	
Geographic Boundaries	34° 14.92' N	
	136° 47.11' E	142° 0.12' E
	2° 19.81' S	
Stations	124	
Floats and drifters deployed	One drifting ocean data buoy	
Moorings deployed or recovered	0	

Recent Contact Information:

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LINKS TO SELECT TOPICS

Shaded sections are not relevant to this cruise or were not available when this report was compiled.

Cruise Summary Information	Hydrographic Measurements
Description of Scientific Program	CTD Data:
Geographic Boundaries	Acquisition
Cruise Track (Figure): PI CCHDO	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Temperature Pressure
Bottle Depth Distributions (Figure)	Salinities Oxygens
Floats and Drifters Deployed	Bottle Data
Moorings Deployed or Recovered	Salinity
	Oxygen
Principal Investigators	Nutrients
Cruise Participants	Carbon System Parameters
	CFCs
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	Radiocarbon
Underway Data Information	References
Navigation Bathymetry	
Acoustic Doppler Current Profiler (ADCP)	
Thermosalinograph	
XBT and/or XCTD	
Meteorological Observations	Acknowledgments
Atmospheric Chemistry Data	
Data Processing Notes	

Contents

A. Cruise narrative

- 1. Highlights*
- 2. Cruise Summary Information*
- 3. List of Principal Investigators for all Measurements*
- 4. Scientific Program and Methods*
- 5. Major Problems and Goals not Achieved*
- 6. List of Cruise Participants*

B. Underway measurements

- 1. Navigation and Bathymetry*
- 2. Maritime Meteorological Observations*
- 3. Thermo-Salinograph (in preparation)*
- 4. $p\text{CO}_2$ (in preparation)*
- 5. Chlorophyll-a*
- 6. Acoustic Doppler Current Profiler*

C. Hydrographic Measurement Techniques and Calibration

- 1. CTD/ O_2 Measurements*
- 2. Bottle Salinity*
- 3. Bottle Oxygen*
- 4. Nutrients*
- 5. Total Dissolved Inorganic Carbon (DIC) / Total Alkalinity (TA) (in preparation)*
- 6. pH (in preparation)*
- 7. Chlorofluorocarbon (CFC-11 and CFC-12) (in preparation)*
- 8. Phytopigment (Chlorophyll-a and phaeopigments)*
- 9. Lowered Acoustic Doppler Current Profiler*

A. Cruise narrative

1. Highlights

Cruise designation: RF10-05 (WHP-P09 revisit)

a. EXPOCODE: 49UP20100706

b. Chief scientist: Toshiya NAKANO (nakano_t@met.kishou.go.jp)

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FAX: +81-3-3211-6908

c. Ship name: R/V Ryofu Maru

d. Ports of call: Leg 1: Tokyo - Palau, Leg 2: Palau - Saipan

e. Cruise dates: Leg 1: 6 July 2010 - 28 July 2010

Leg 2: 1 August 2010 - 22 August 2010

f. Floats and drifters deployed: one drifting ocean data buoy

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2. Cruise Summary Information

RF10-05 cruise was carried out during the period from July 6 to September 1, 2010. The cruise started from the south of Honshu, Japan, and sailed towards south along approximately 137°E meridian. This line was observed by JMA in 1994 as ‘WHP-P9’, which is a part of WOCE (World Ocean Circulation Experiment) Hydrographic Programme.

A total of 124 stations was occupied using a Sea-Bird Electronics (SBE) 36 position carousel equipped with 10-liter Niskin water sample bottles, a CTD system (SBE911plus) equipped with SBE35 deep ocean standards thermometer, JFE Advantech oxygen sensor (RINKO III), Teledyne Benthos altimeter, and Teledyne RD Instruments Lowered Acoustic Doppler Current Profiler (L-ADCP). To examine consistency of data, we carried out the observation three times at 7°N, 137°E (Stn.67, 68 and 124) and twice at 2°N, 142°E (Stn.83 and 104). Cruise track and station location are shown in [Figure 1](#).

At each station, full-depth CTDO₂ (temperature, conductivity (salinity) and dissolved oxygen) profile and up to 36 water samples were taken and analyzed. Water samples were obtained from 10 dbar to approximately 10 m above the bottom. In addition, surface water was sampled by a stainless steel bucket at each station. Sampling layer is designed as so-called staggered mesh as shown in [Table 1](#) (Swift, 2010). The bottle depth diagram is shown in [Figure 2](#).

Water samples were analyzed for salinity, dissolved oxygen, nutrients, dissolved inorganic carbon (DIC), total alkalinity (TA), pH, CFC-11, CFC-12 and phytopigment (chlorophyll-a and phaeopigments). Samples for dissolved organic carbon (DOC) and ¹³C were also collected at the selected stations. Underway measurements of partial pressure of carbon dioxide (*p*CO₂), temperature, salinity, chlorophyll-a, subsurface current, bathymetry and meteorological parameters were conducted along the cruise track.

R/V Ryofu Maru departed Tokyo (Japan) on July 6, 2010. Before the observation at the first station, all watch standers were drilled in the method of sample drawing and CTD operations

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near Izu-Oshima (34°40'N, 139°37'E). In order to estimate the misalignment of the ship-mounted Acoustic Doppler Current Profiler (ADCP), we collected the bottom tracking data for about an hour off Omaezaki (around 34°22'N, 137°55'E). The hydrographic cast of CTDO₂ was started at the first station (Stn.1 (34°15'N, 137°E; RF3649)) on July 7. Leg 1 consisted of 67 stations from Stn.1 to Stn.67 (7°N, 137°E; RF3715). She called for Palau (Republic of Palau) on July 28, 2010 (Leg 1). She left Palau on August 1, 2010 for Saipan (Commonwealth of the Northern Mariana Islands) and arrived on August 22, 2010 (Leg 2). Leg 2 consisted of 57 stations from Stn.68 (7°N, 137°E; RF3716) to Stn.124 (7°N, 137°E; RF3772).

To wait the issue of a clearance letter for the EEZ of Papua New Guinea, we carried out from Stn.105 (2°03'N, 141°45'E; RF3732) to Stn.107 (2°09'N, 141°15'E; RF3734) after observation at Stn.83 (2°N, 142°E; RF3731) on August 5. After the issue of the clearance letter, we resumed from Stn.84 (1°45'N, 142°E; RF3735) on August 6. To carry out four stations from Stn.100 (2°05'S, 141°45'E; RF3750) to Stn.103 (2°22'S, 141°08'E; RF3747) near the coast of Papua New Guinea during the daytime, we sailed to Stn.103 (2°22'S, 141°08'E; RF3747) after at Stn.95 (1°S, 142°E; RF3746), and resumed on August 9.

One drifting ocean data buoy (WMO number: 21595) was deployed at 32°01.988'N, 137°00.620'E on July 8, 2010.

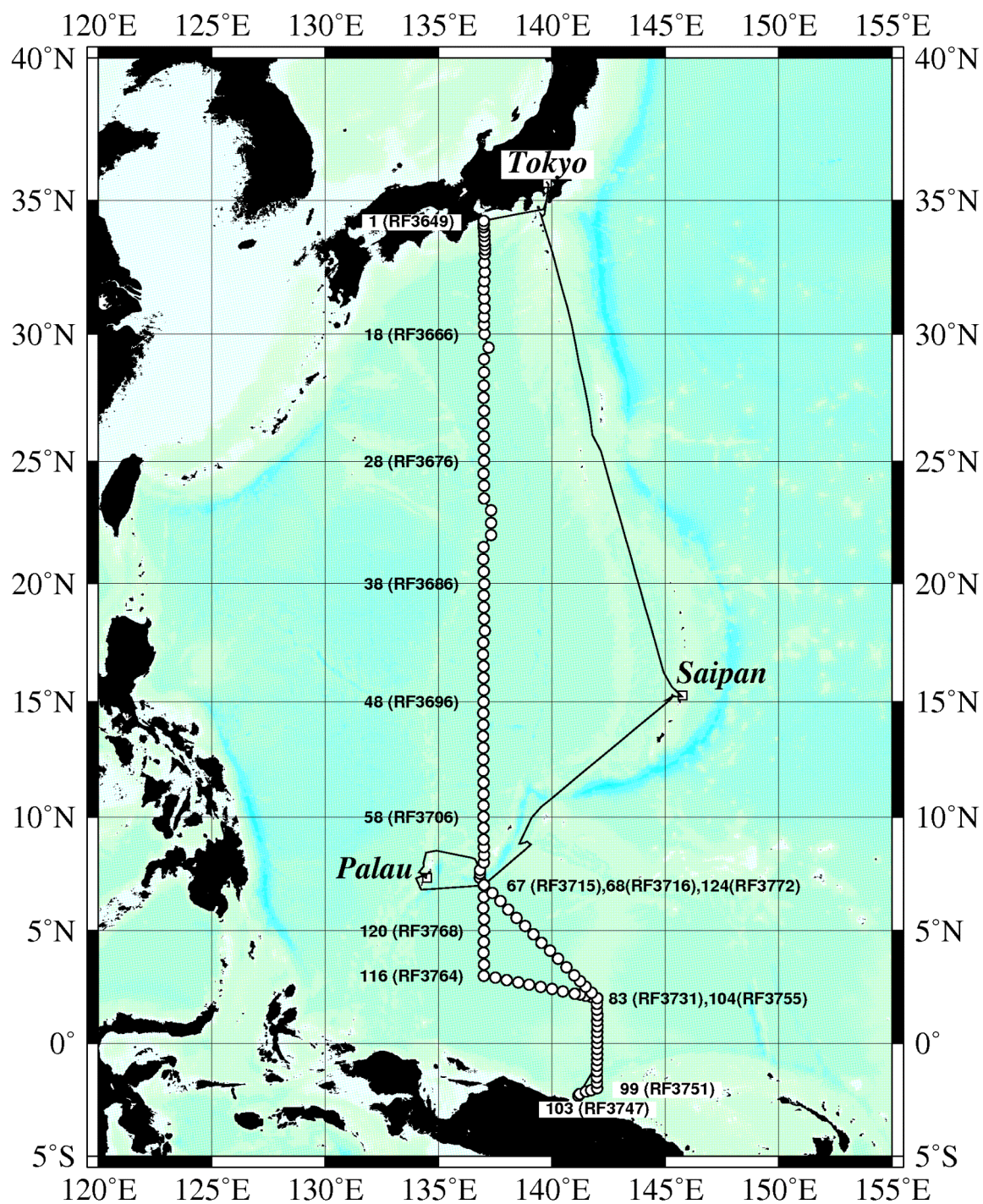


Figure 1. Cruise track of RF10-05.

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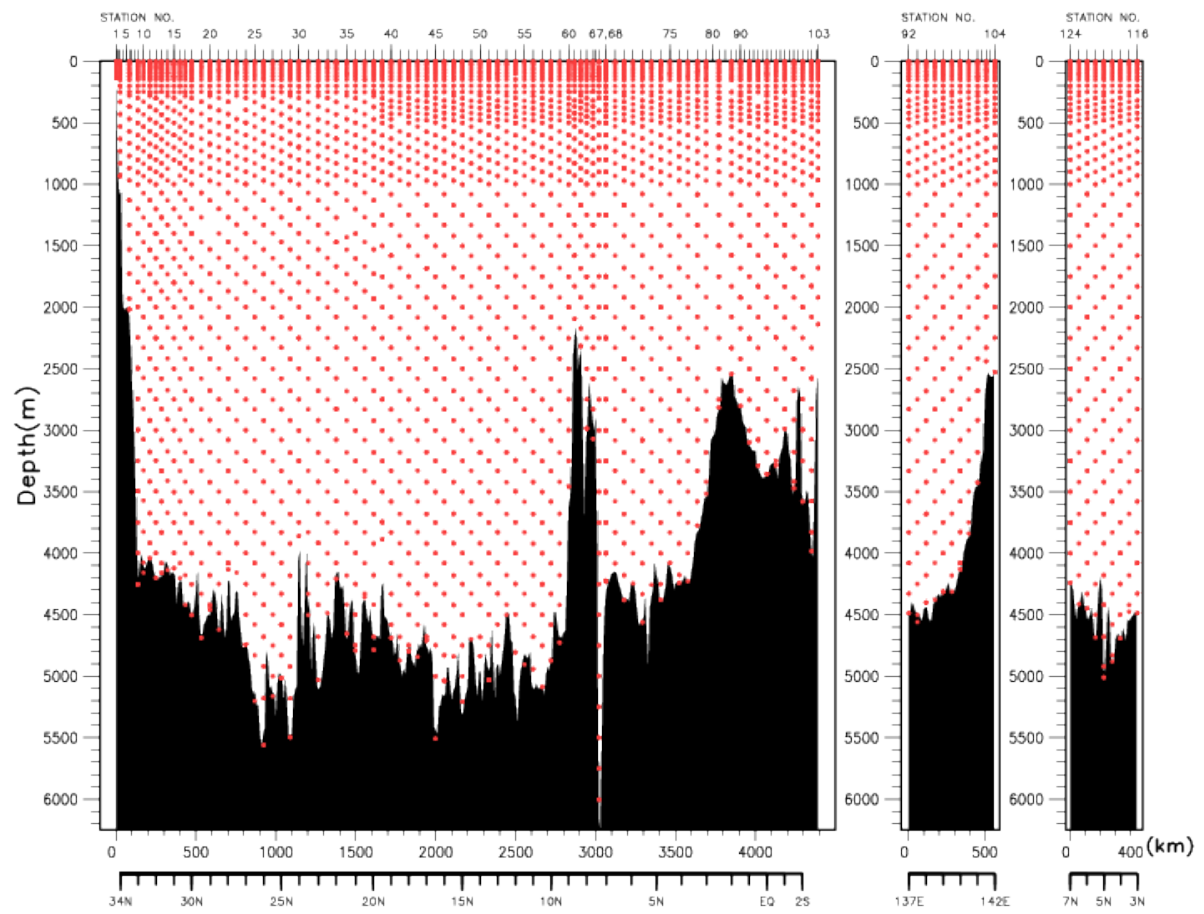


Figure 2. The bottle depth diagram for WHP-P9 revisit.

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Table 1. The scheme of sampling layer in meters.

	North of 20°N (Stn.1 - Stn.38)			South of 20°N (Stn.38 - Stn.124)			Yap Trench (Stn.66)
<i>Bottle count</i>	<i>scheme1</i>	<i>scheme2</i>	<i>scheme3</i>	<i>scheme4</i>	<i>scheme5</i>	<i>scheme6</i>	<i>scheme7</i>
1	10	10	10	10	10	10	10
2	25	25	25	25	25	25	50
3	50	50	50	50	50	50	75
4	75	75	75	75	75	75	100
5	100	100	100	100	100	100	125
6	125	125	125	125	125	125	150
7	150	150	150	150	150	150	200
8	200	200	200	200	200	200	250
9	250	250	250	250	250	250	300
10	300	330	280	300	320	280	400
11	400	430	370	350	370	330	500
12	500	530	470	400	420	380	600
13	600	630	570	450	470	430	700
14	700	730	670	500	530	480	800
15	800	830	770	600	630	570	900
16	900	930	870	700	730	670	1000
17	1000	1070	970	800	830	770	1250
18	1200	1270	1130	900	930	870	1500
19	1400	1470	1330	1000	1080	970	1750
20	1600	1670	1530	1250	1330	1170	2000
21	1800	1870	1730	1500	1580	1420	2250
22	2000	2080	1930	1750	1830	1680	2500
23	2250	2330	2170	2000	2080	1920	2750
24	2500	2580	2420	2250	2330	2170	3000
25	2750	2830	2680	2500	2580	2420	3250
26	3000	3080	2920	2750	2830	2680	3500
27	3250	3330	3180	3000	3080	2920	3750
28	3500	3580	3420	3250	3330	3180	4000
29	3750	3830	3680	3500	3580	3420	4250
30	4000	4080	3920	3750	3830	3680	4500
31	4250	4330	4180	4000	4080	3920	4750
32	4500	4580	4420	4250	4330	4180	5000
33	4750	4830	4680	4500	4580	4420	5250
34	5000	5080	4920	4750	4830	4680	5500
35	5250	5330	5180	5000	5080	4920	5750
36	5500	5580	5420	5250	5330	5180	6000

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Table 2. Station data of RF10-05 cruise. The ‘RF’ column indicates the JMA station identification number.

<i>Leg</i>	<i>Station</i>		<i>Position</i>		<i>Leg</i>	<i>Station</i>		<i>Position</i>	
	<i>Stn.</i>	<i>RF</i>	<i>Latitude</i>	<i>Longitude</i>		<i>Stn.</i>	<i>RF</i>	<i>Latitude</i>	<i>Longitude</i>
1	1	3649	34-14.85 N	136-59.47 E	1	36	3684	20-59.83 N	136-58.21 E
1	2	3650	34-06.71 N	136-59.24 E	1	37	3685	20-29.06 N	136-59.41 E
1	3	3651	34-00.94 N	136-58.40 E	1	38	3686	19-58.25 N	137-00.39 E
1	4	3652	33-50.14 N	137-00.82 E	1	39	3687	19-29.39 N	136-59.28 E
1	5	3653	33-41.22 N	137-00.79 E	1	40	3688	18-59.74 N	136-59.04 E
1	6	3654	33-30.31 N	137-01.55 E	1	41	3689	18-30.52 N	136-59.94 E
1	7	3655	33-21.12 N	137-02.20 E	1	42	3690	18-00.58 N	137-01.81 E
1	8	3656	33-11.27 N	137-02.34 E	1	43	3691	17-30.53 N	136-57.81 E
1	9	3657	33-01.56 N	137-02.01 E	1	44	3692	17-00.27 N	136-57.57 E
1	10	3658	32-42.25 N	137-00.65 E	1	45	3693	16-30.38 N	136-58.83 E
1	11	3659	32-20.90 N	137-01.94 E	1	46	3694	16-00.61 N	136-58.58 E
1	12	3660	32-00.61 N	137-00.75 E	1	47	3695	15-29.31 N	136-59.09 E
1	13	3661	31-41.64 N	136-58.71 E	1	48	3696	14-58.91 N	136-58.90 E
1	14	3662	31-21.19 N	137-00.50 E	1	49	3697	14-29.66 N	136-58.10 E
1	15	3663	30-59.46 N	137-01.14 E	1	50	3698	14-00.03 N	136-58.18 E
1	16	3664	30-39.21 N	136-59.69 E	1	51	3699	13-29.87 N	136-57.56 E
1	17	3665	30-21.57 N	136-59.92 E	1	52	3700	12-59.96 N	136-58.26 E
1	18	3666	30-00.10 N	137-01.43 E	1	53	3701	12-30.05 N	136-58.33 E
1	19	3667	29-28.67 N	137-11.93 E	1	54	3702	12-00.31 N	136-58.25 E
1	20	3668	29-01.75 N	136-59.89 E	1	55	3703	11-29.76 N	136-58.70 E
1	21	3669	28-31.08 N	137-00.02 E	1	56	3704	11-00.26 N	136-58.61 E
1	22	3670	27-59.90 N	136-59.33 E	1	57	3705	10-29.85 N	136-58.61 E
1	23	3671	27-31.45 N	136-58.97 E	1	58	3706	10-00.08 N	136-58.83 E
1	24	3672	27-00.52 N	136-59.86 E	1	59	3707	9-30.74 N	136-58.65 E
1	25	3673	26-30.40 N	136-57.70 E	1	60	3708	9-00.24 N	136-58.45 E
1	26	3674	25-59.83 N	136-59.19 E	1	61	3709	8-40.27 N	136-59.58 E
1	27	3675	25-29.17 N	136-59.31 E	1	62	3710	8-20.10 N	136-59.98 E
1	28	3676	25-00.65 N	137-00.21 E	1	63	3711	7-59.77 N	136-59.20 E
1	29	3677	24-30.44 N	136-58.66 E	1	64	3712	7-40.05 N	136-49.64 E
1	30	3678	24-00.94 N	136-59.92 E	1	65	3713	7-30.48 N	136-49.37 E
1	31	3679	23-29.77 N	136-59.67 E	1	66	3714	7-20.26 N	136-48.74 E
1	32	3680	23-00.92 N	137-18.82 E	1	67	3715	7-00.04 N	136-58.93 E
1	33	3681	22-29.37 N	137-18.40 E	2	68	3716	7-00.88 N	136-59.76 E
1	34	3682	21-59.97 N	137-18.57 E	2	69	3717	6-39.49 N	137-21.88 E
1	35	3683	21-29.80 N	136-58.52 E	2	70	3718	6-17.74 N	137-43.07 E

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Table 2. Continue.

<i>Leg</i>	<i>Station</i>		<i>Position</i>		<i>Leg</i>	<i>Station</i>		<i>Position</i>	
	<i>Stn.</i>	<i>RF</i>	<i>Latitude</i>	<i>Longitude</i>		<i>Stn.</i>	<i>RF</i>	<i>Latitude</i>	<i>Longitude</i>
2	71	3719	5-55.67 N	138-03.99 E	2	101	3749	2-08.67 S	141-29.57 E
2	72	3720	5-33.31 N	138-25.79 E	2	102	3748	2-15.11 S	141-13.64 E
2	73	3721	5-11.89 N	138-48.44 E	2	103	3747	2-19.60 S	141-09.45 E
2	74	3722	4-50.02 N	139-10.52 E	2	104	3755	1-59.43 N	142-00.12 E
2	75	3723	4-27.07 N	139-31.75 E	2	105	3732	2-03.14 N	141-44.45 E
2	76	3724	4-06.04 N	139-54.57 E	2	106	3733	2-06.16 N	141-29.56 E
2	77	3725	3-44.95 N	140-15.73 E	2	107	3734	2-09.49 N	141-13.84 E
2	78	3726	3-21.94 N	140-37.71 E	2	108	3756	2-11.70 N	140-59.67 E
2	79	3727	3-00.77 N	140-58.68 E	2	109	3757	2-17.51 N	140-28.74 E
2	80	3728	2-45.45 N	141-14.11 E	2	110	3758	2-24.22 N	139-59.72 E
2	81	3729	2-30.34 N	141-28.92 E	2	111	3759	2-30.02 N	139-30.12 E
2	82	3730	2-14.41 N	141-44.74 E	2	112	3760	2-35.75 N	138-59.52 E
2	83	3731	1-59.46 N	141-59.05 E	2	113	3761	2-41.87 N	138-30.87 E
2	84	3735	1-44.79 N	141-58.73 E	2	114	3762	2-47.99 N	138-00.11 E
2	85	3736	1-29.52 N	141-58.56 E	2	115	3763	2-54.55 N	137-29.93 E
2	86	3737	1-14.31 N	141-59.87 E	2	116	3764	2-59.58 N	136-59.63 E
2	87	3738	0-59.52 N	141-59.07 E	2	117	3765	3-29.59 N	136-59.81 E
2	88	3739	0-44.71 N	141-59.89 E	2	118	3766	4-01.31 N	136-58.47 E
2	89	3740	0-29.62 N	141-59.51 E	2	119	3767	4-29.55 N	136-59.55 E
2	90	3741	0-14.50 N	141-59.26 E	2	120	3768	4-59.94 N	136-59.75 E
2	91	3742	0-00.24 N	141-59.11 E	2	121	3769	5-30.16 N	137-00.06 E
2	92	3743	0-15.42 S	141-59.21 E	2	122	3770	5-59.22 N	136-58.21 E
2	93	3744	0-29.95 S	141-59.54 E	2	123	3771	6-29.06 N	136-59.06 E
2	94	3745	0-44.90 S	141-59.39 E	2	124	3772	7-00.20 N	136-59.16 E
2	95	3746	1-00.14 S	141-58.81 E					
2	96	3754	1-15.01 S	141-58.48 E					
2	97	3753	1-31.09 S	141-58.78 E					
2	98	3752	1-45.22 S	141-58.92 E					
2	99	3751	2-00.11 S	141-59.09 E					
2	100	3750	2-05.25 S	141-43.59 E					

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3. List of Principal Investigators for all Measurements

The principal investigator (PI) and the person in charge responsible for major parameters measured on the cruise are listed in Table 3.

Table 3. List of principal investigator and the person in charge on the ship for RF10-05.

Item	Principal Investigator (PI)	Person in charge on the ship
<u>Hydrography</u>		
CTDO ₂ / LADCP	Hitomi KAMIYA	Tetsuya NAKAMURA
Salinity	Hitomi KAMIYA	Keizo SHUTTA
Dissolve oxygen	Hitomi KAMIYA	Yusuke TAKATANI
Nutrients	Hitomi KAMIYA	Takahiro KITAGAWA
Phytopigment	Hitomi KAMIYA	Yusuke TAKATANI
DIC	Hitomi KAMIYA	Shinji MASUDA
Total Alkalinity	Hitomi KAMIYA	Shinji MASUDA
pH	Hitomi KAMIYA	Shinji MASUDA
CFCs	Hitomi KAMIYA	Kazuki ISHIMARU
DOC	Masao ISHII	Shinji MASUDA
¹³ C	Masao ISHII	Shinji MASUDA
<u>Underway</u>		
Meteorology	Hitomi KAMIYA	Keizo SHUTTA
Thermo-Salinograph	Hitomi KAMIYA	Shinji MASUDA
pCO ₂	Hitomi KAMIYA	Shinji MASUDA
Chlorophyll-a	Hitomi KAMIYA	Yusuke TAKATANI
ADCP	Hitomi KAMIYA	Tetsuya NAKAMURA
Bathymetry	Hitomi KAMIYA	Takahiro SEGAWA

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4. Scientific Program and Methods

In recent years, the global environmental issues such as global warming and climate change have become one of the major socio-economic concerns, and it has become apparent that the ocean plays a key role in the climate system. For the better understanding and assessment of global environmental conditions, continuous monitoring of climate variables, concentrations of greenhouse gases both in the ocean and in the atmosphere. To meet those requirements, JMA has been conducting operational oceanographic observations by research vessels in the western North Pacific on a seasonal basis. RF10-05 cruise is one of these activities. The purposes of this cruise are as follows:

- (1) To observe profiles of seawater temperature, salinity, dissolved oxygen, nutrients and carbon parameters, as well as upper ocean current;
- (2) To observe concentrations of greenhouse gases both in the ocean and in the atmosphere;
- (3) To observe bio-geochemical parameters to study carbon cycle in the ocean.

These activities are expected to contribute to international projects related to global environmental issues such as the World Climate Research Programme (WCRP), IOCCP (International Ocean Carbon Coordination Project) and the Global Atmosphere Watch (GAW).

5. Major Problems and Goals not Achieved

Owing to kink in the wire, we reconnected the CTD cable at Stn.19 (29°30'N, 137E; RF3667). After the observation at Stn.104 (2° N, 142°E; RF3755), owing to damage in the wire, we cut the wire about 700 m in length, and reconnected the CTD cable.

6. List of Cruise Participants

The cruise participants of the cruise is listed in Table 4.

Table 4. List of cruise participants for RF10-05.

Name	Responsibility	Affiliation
Yasuaki BUNGI	Salinity	GEMD / JMA
Kazutaka ENYO	Carbon Items	GEMD / JMA
Hiroyuki FUJIWARA	Nutrients	GEMD / JMA
Sho HIBINO	Dissolved Oxygen	GEMD / JMA
Yoshikazu HIGASHI	CTDO / ADCP / LADCP	GEMD / JMA
Kazuki ISHIMARU	CFCs	GEMD / JMA
Takahiro KITAGAWA	Nutrients	GEMD / JMA
Tomoyuki KITAMURA	CTDO / ADCP / LADCP	GEMD / JMA
Naohiro KOSUGI	Carbon Items	MRI / JMA
Shinji MASUDA	Carbon Items / Thermo-Salinograph	GEMD / JMA
Tetsuya NAKAMURA	CTDO / ADCP / LADCP	GEMD / JMA
Toshiya NAKANO	Chief Scientist	GEMD / JMA
Etsuro ONO	CFCs	GEMD / JMA
Takahiro SEGAWA	Salinity / Bathymetry	GEMD / JMA
Kazuhiro SAITO	Nutrients	GEMD / JMA
Keizo SHUTTA	Salinity / Meteorology	GEMD / JMA
Yusuke TAKATANI	Dissolved Oxygen / Phyt pigment	GEMD / JMA
Shinichiro UMEDA	Dissolved Oxygen / Phyt pigment	GEMD / JMA

GEMD / JMA: Marine Division, Global Environment and Marine Department, JMA

MRI / JMA: Geochemical Research Department, Meteorological Research Institute, JMA

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Reference

Swift, J. H. (2010): Reference-quality water sample data: Notes on acquisition, record keeping, and evaluation. *IOCCP Report No.14, ICPO Pub. 134, 2010 ver.1.*

B. Underway measurements

1. Navigation and Bathymetry

(1) Personnel

Takahiro SEGAWA (GEMD/JMA)

Tetsuya NAKAMURA (GEMD/JMA)

Keizo SHUTTA (GEMD/JMA)

Yoshikazu HIGASHI (GEMD/JMA)

Tomoyuki KITAMURA (GEMD/JMA)

Yasuaki BUNGI (GEMD/JMA)

(2) Navigation

(2.1) Overview of the equipment

The ship's position was measured by navigation system made by FURUNO ELECTRIC CO., LTD. JAPAN. The system has two 3-channels GPS receivers (GP-80, GP-150). GPS antennas was installed at Compass deck. We switched the receivers to choose better receiving state if the number of GPS satellites decreased or HDOP increased. GPS data, gyro heading and log speed were integrated and delivered to two workstations. One workstation works as primary NTP (Network Time Protocol) server and the other works secondary server.

The navigation data were obtained approximately every one second and one minute data were extract from one second data. These one minute data were recorded as "LOG data".

(2.2) Data Period

05:00, 06 Jul. 2010 to 00:00, 1 Sep. 2010(UTC)

(3) Bathymetry

(3.1) Overview of the equipment

R/V Ryofu Maru equipped a single beam echo sounder, Kongsberg EA 600 (SIMRAD Fisheries Research, Norway). The main objective of the survey is collecting continuous bathymetry data along ship's track. At first we set up system choosing 1500 m/s for sound speed. During the cruise, we used averaged sound velocity data obtained from the nearest CTD cast to get accurate depth data. Data interval was about 8 seconds at 6000m.

(3.2) System Configuration and Performance

System:	Kongsberg EA 600
Frequency:	12kHz
Transmit power:	2kW
Transmit pulse interval:	Within 20seconds
Depth range:	5 to 15,000m
Depth resolution:	1cm
Depth accuracy:	Within 20cm

(3.3) Data Period

The collecting bathymetry data was carried out during the cruise except for port of Palau and Saipan.

05:00, 06 Jul. 2010 to 00:00, 1 Sep. 2010(UTC)

(3.4) Data Processing

The bathymetry data are obtained using a mean sound velocity calculated from the data of nearest CTD cast. The formula of the sound velocity calculated in SEASAVE, CTD data acquisition software, is *Chen and Millero (1977)*. The system combines bathymetry data with navigation data, so the data file consists of date, time, location, depth and flag of bathymetry data.

If the erroneous data were obtained, the bathymetry data flag was set to '9' and the data was

set to '0' automatically.

Reference

Chen, C.-T. and F. J. Millero (1977): Speed of sound in seawater at high pressures. *J. Acoust. Soc. Am.* **62**(5), 1129-1135.

2. Maritime Meteorological Observations

(1) Personnel

Keizo SHUTTA (GEMD/JMA)

Tetsuya NAKAMURA (GEMD/JMA)

Takahiro SEGAWA (GEMD/JMA)

Yoshikazu HIGASHI (GEMD/JMA)

Yasuaki BUNGI (GEMD/JMA)

Tomoyuki KITAMURA (GEMD/JMA)

(2) Data Period

09:00, 6 Jul. 2010 to 23:00, 31 Aug. 2010(UTC)

(3) Methods

The maritime meteorological observation system on R/V Ryofu Maru is Ryofu Maru maritime meteorological measurement station (RMET). Instruments of RMET are listed in [Table B.2.1](#). All RMET data were collected and processed by KOAC-7800 weather data processor made by Koshin Denki Kogyo CO., Ltd. Japan.

[Figure B.2.1](#) and [B.2.2](#) show maritime meteorological observation data.

Table B.2.1. Instruments and locations of RMET.

Sensor	Parameter	Manufacture (Type)	Location (Height from maximum load line)
Thermometer	Air Temperature	Koshin Denki Kogyo (Electric type)	Compass deck (13.3m)
Hygrometer	Relative humidity	Koshin Denki Kogyo (Electrostatic type)	Compass deck (13.3 m)
Thermometer	Sea Temperature	Koshin Denki Kogyo (Electric type)	Engine Room (−4.7 m)
Aerovane	Wind Speed	Koshin Denki Kogyo	Mast top
	Wind Direction	(Propellar type)	(19.8 m)
Wave gauge	Wave Height	Tsurumi-Seiki	Ship front
	Wave period	(Micro wave type)	(6.5 m)
Barometer	Pressure	Koshin Denki Kogyo (Electrostatic type)	Observation room (2.8 m)

Note that there are two set of thermometer and hygrometer at starboard and port sides.

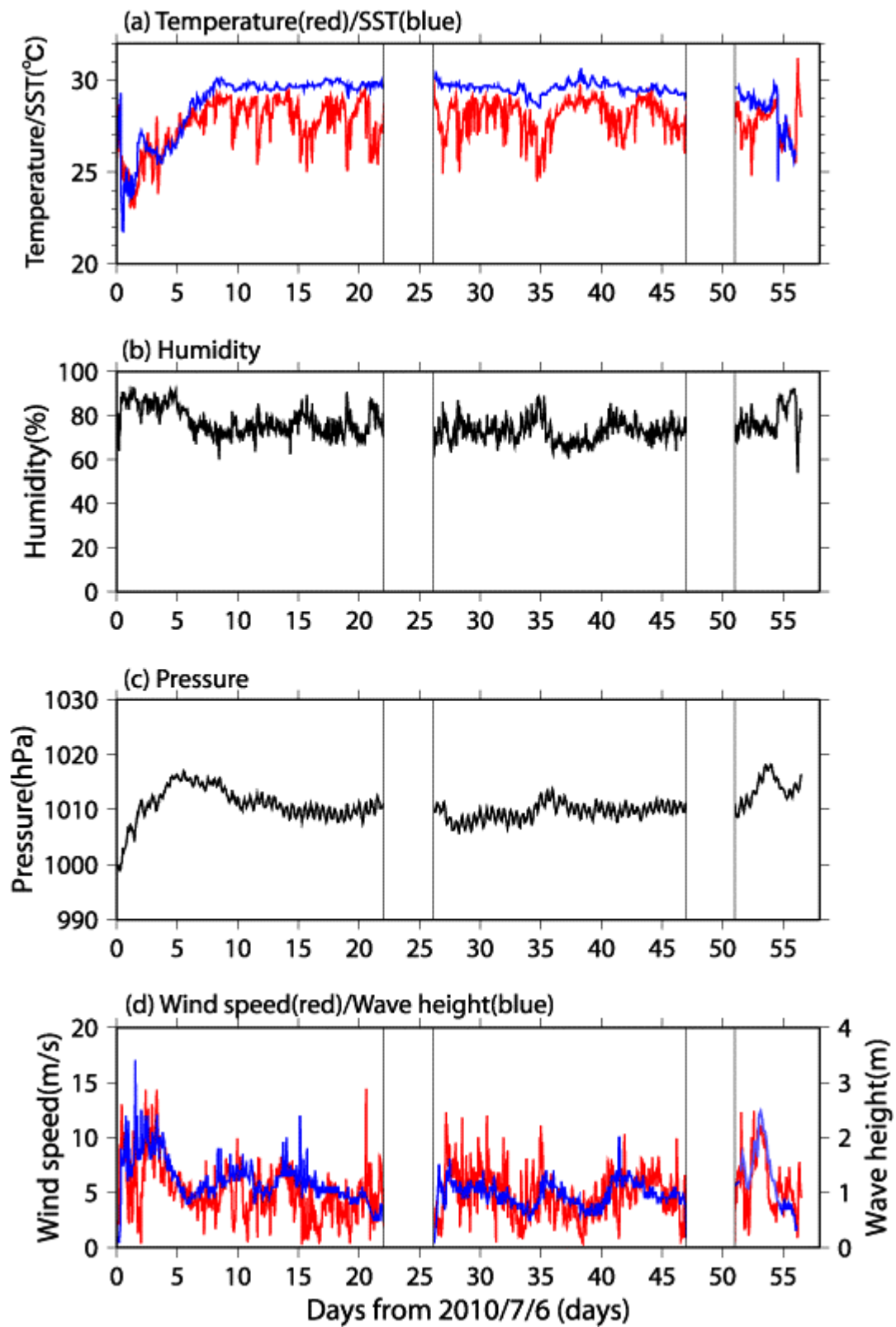


Figure B.2.1. Time series of (a) air and sea surface temperature, (b) relative humidity, (c) pressure, (d) wind speed and wave height. The light blue in (d) panel, light blue line shows the non-instrumental observation of wave height. Day 0 correspond to July 6 (JST), 2010.

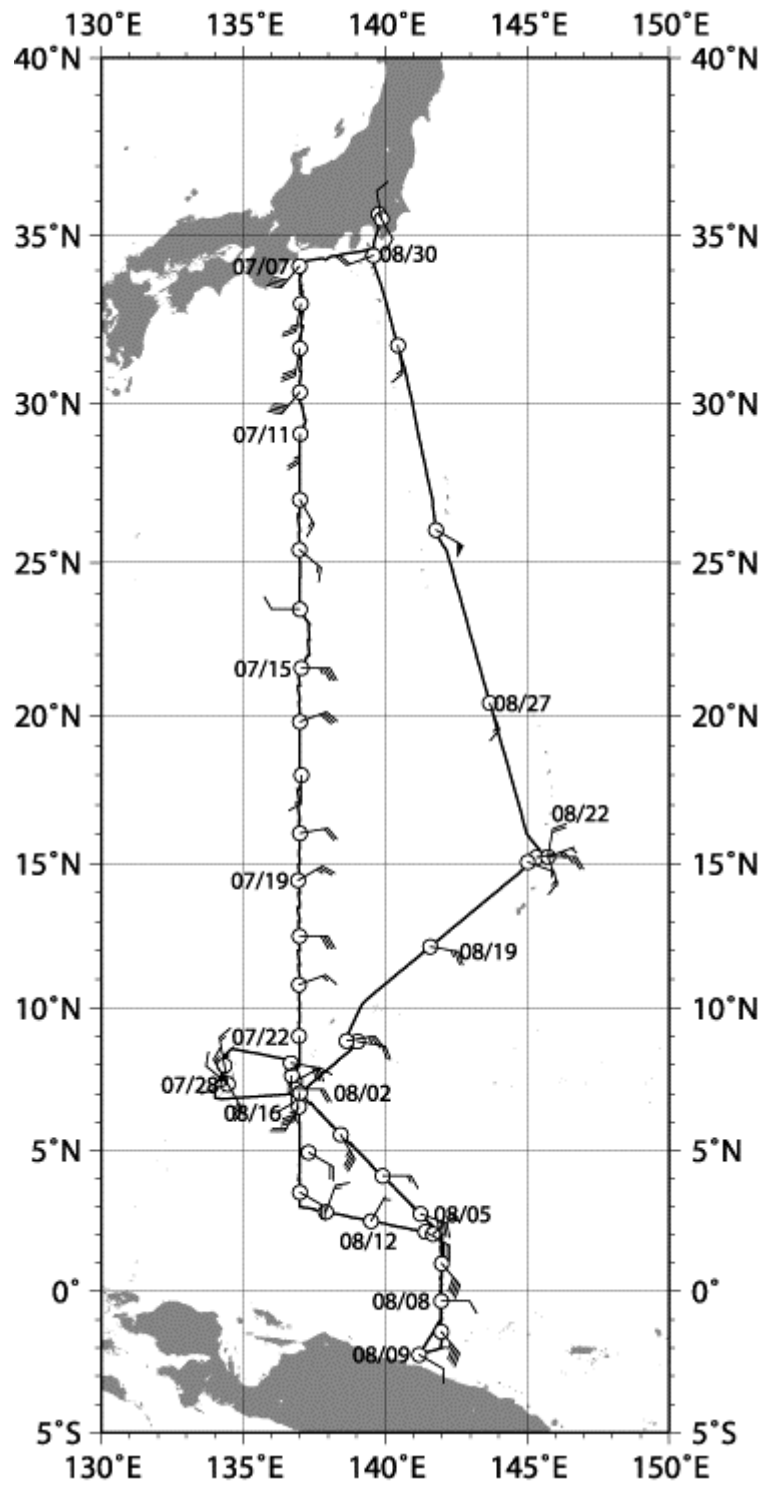


Figure B.2.2. Wind vector along Ryofu Maru at every noon position. Black flag corresponds to 10m/s, long line corresponds to 2m/s and short line corresponds to 1m/s.

(4) Data processing and Data format

All raw data were recorded every 6-seconds. 1-minute and 10-minute values are averaged from 6-seconds values. 10-minute value of every three hours is available at JMA web site (http://www.data.kishou.go.jp/kaiyou/db/vessel_obs/data-report/html/ship/cruisedata_e.php?id=RF1005).

Since the thermometers and hygrometers are equipped on both starboard/port sides on the Compass deck, we used air temperature/relative humidity data taken at upwind side. Dew point temperature was calculated from relative humidity and air temperature data.

No adjustment to sea level values is applied except for pressure data. During the cruise, fixed value +0.5hPa is used for sea level correction. Data are stored in ASCII format and representative parameters are as follows. Time in UTC, longitude (E), latitude (N), ship speed (knot), ship direction (degrees), sea surface pressure (hPa), air temperature (degrees Celsius), dew point temperature (degrees Celsius), relative humidity (%), sea surface temperature (degrees Celsius), wind direction (degree) and wind speed (m/sec).

Wave height and period are observed twice an hour. The sampling duration is 20 minutes and each sampling starts at 5 minutes and 35 minutes after the hour. In addition to those data, ship's position and observation time are recorded in ASCII format.

(5) Data quality

To ensure the data quality, each sensor was checked as follows.

Temperature/Relative humidity sensor:

Temperature and relative humidity (T/RH) sensors were checked by manufacturer and, they were also checked by using calibrated Asman psychrometer before the cruise and arrival at the port. The discrepancy between T/RH sensors and Asman psychrometer were within ± 0.4 degrees Celsius and ± 4 % respectively at both sides.

Thermometer (Sea Temperature):

Sea temperature sensor was calibrated once per year by the manufacturer. Certificated accuracy of sea temperature sensor is better than ± 0.4 degrees Celsius. The values are also compared with bucket samples after the departure.

Pressure sensor:

Using calibrated portable barometer (Vaisala 765-16B, certificated accuracy is better than ± 0.1 hPa), pressure sensor was checked before the cruise. Mean difference of RMET pressure sensor and portable sensor is less than 0.7 hPa.

Aerovane:

Aerovane was checked once per year by the manufacturer and, once per five years by the Meteorological Instrument Center, JMA.

(6) Ship's weather observation

Non-instrumental observations such as weather, cloud, visibility, wave direction and wave height were made by the ship crews every three hours. We sent those data together with RMET data to the Global Collecting Centre for Marine Climatological Data in IMMT (International Maritime Meteorological Tape) -III format. The RMET data is available at JMA web site.

(http://www.data.kishou.go.jp/kaiyou/db/vessel_obs/data-report/html/ship/cruisedata_e.php?id=RF1005).

5. Chlorophyll-*a*

(1) Personnel

Yusuke TAKATANI (GEMD/JMA)

Shinichiro UMEDA (GEMD/JMA)

(2) Method

The Continuous Sea Surface Water Monitoring System of fluorescence (Nippon Kaiyo Co. Ltd.) automatically had been continuously measured seawater which is pumped from a depth of about 4.5 m below the maximum load line to the laboratory. The flow rate of the surface seawater was controlled by several valves and adjusted to about 0.6 L/min. The sensor in this system is a fluorometer (10-AU, S/N:7063) manufactured by Turner Designs. The system measured every one minute.

(3) Measurement

Periods of measurement and problems are listed in [Table B.5.1](#).

(4) Calibration

In order to calibrate the fluorescence sensor, we collected 200 ml of surface seawater from outlet of water line of the system for measuring chlorophyll-*a*. The seawater samples were collected at nominally 60 N. miles intervals. The seawater sample was gently filtrated by low vacuum pressure through Whatman GF/F filter (diameter 25mm). The filter was immediately transferred into 9 ml of N, N-dimethylformamide (DMF) and then stored at –30°C to extract chlorophyll-*a* for more than 24 hours. Concentrations of chlorophyll-*a* were measured by a fluorometer (10-AU, S/N: 6718, TURNER DESIGNS) that was previously calibrated against a pure chlorophyll-*a* (Lot.:BCBB4166, Sigma chemical Co.) by the method described in UNESCO (1994). In order to calibrate the fluorometer, fluorometric measurement of chlorophyll-*a* was performed by the method of *Holm-Hansen et al.* (1965) and *Holm-Hansen and Riemann* (1978). The results of the measurements are shown in [Table B.5.2](#). The fluorescence sensor may be contaminated while measuring. Therefore, we calibrated the

fluorescence value of the sensor to 0 (deionized water) and 10 (0.1 ppm Rhodamine solution) at the start of a leg, and measured a solution of the same concentration at the end of a leg. The results are shown in [Table B.5.3](#).

The data is calculated by the following procedure;

- The fluorescence value of the sensor is calibrated by deionized water and a Rhodamine solution at the starting and the ending.
- The ratio between a calibrated fluorescence value and a chlorophyll-*a* concentration of a seawater sample is interpolated by distance.
- The chlorophyll-*a* concentration is calculated by multiplying a calibrated fluorescence value by an interpolated ratio.

(5) Data and Result

Quality controlled data, those file name is “20120202_p09_in-vivo.txt”, is distributed by JMA format. The record structure of JMA format is shown below.

Column1: observed date [UTC]

Column2: observed time [UTC]

Column3: observed latitude

Column4: observed longitude

Column5: fluorescence value

Column6: fluorescence value calibrated by deionized water and a Rhodamine solution

Column7: ratio between a calibrated fluorescence value and a chlorophyll-*a* concentration of a seawater sample interpolated by distance

Column8: calculated chlorophyll-*a* concentration (µg/L)

Result of chlorophyll-*a* concentration of underway measurement is shown in [Figure B.4.1](#).

Chlorophyll-*a* data on [Figure B.4.1](#) is averaged over 2-hours.

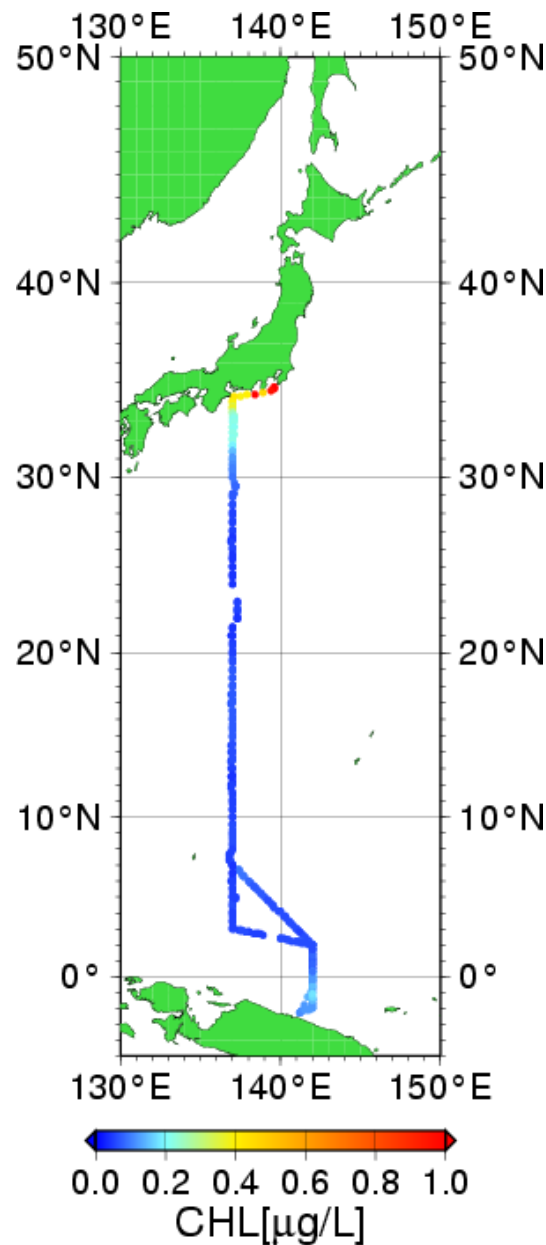


Figure B.4.1. Result of chlorophyll-*a* concentration of underway measurement.

References

- Holm-Hansen, O., and B. Riemann (1978): chlorophyll *a* determination: improvements in methodology. *Oikos*, **30**, 438-447.
- Holm-Hansen, O., C. J. Lorenzen, R. W. Holmes and J. D. H. Strickland (1965): Fluorometric determination of chlorophyll. *J. Cons. Perm. Int. Explor. Mer.*, **30**, 3-15.
- UNESCO (1994), Protocols for the joint global ocean flux study (JGOFS) core measurements: Measurement of chlorophyll *a* and phaeopigments by fluorometric analysis, *IOC manuals and guides* **29**, Chapter 14.

Table B.5.1. Events list of the fluorescence sensor.

Date [UTC]	Time [UTC]	Event
6-Jul-10	08:51	The measurement started. (Leg 1 start)
6-Jul-10	12:19	Error data due to the flow line
6-Jul-10	22:13	Error data due to the flow line
7-Jul-10	00:21	Error data due to the flow line
8-Jul-10	07:26	Error data due to the flow line
8-Jul-10	12:14	Error data due to the flow line
9-Jul-10	12:46	Error data due to the flow line
13-Jul-10 -14-Jul-10	21:54-09:48	Error data due to the flow line.
15-Jul-10	01:43-02:56	Failure of data storage due to the PC trouble.
19-Jul-10	21:33	Error data due to the flow line
23-Jul-10	14:29	The measurement stopped. (Leg 1 end)
2-Aug-10	02:38	The measurement started. (Leg 2 start)
2-Aug-10	05:16-05:25	GPS data error.
4-Aug-10	21:03	Error data due to the flow line
4-Aug-10	22:18	Error data due to the flow line
6-Aug-10	09:41-10:26	Failure of data storage due to the PC trouble.
6-Aug-10	21:10	Error data due to the flow line
7-Aug-10	02:56-03:03	Failure of data storage due to the PC trouble.
7-Aug-10	14:38	Error data due to the flow line
8-Aug-10	05:49-08:00	Failure of data storage due to the PC trouble.
9-Aug-10	04:32	Error data due to the flow line
9-Aug-10	18:50	Error data due to the flow line
10-Aug-10	08:57	Error data due to the flow line
10-Aug-10	13:52	Error data due to the flow line
11-Aug-10	12:35-13:16	Failure of data storage due to the PC trouble.
11-Aug-10 -12-Aug-10	22:09-11:09	Error data due to the flow line.

16-Aug-10	08:51	The measurement stopped. (Leg 2 end)
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Table B.5.2. Comparison of sensor fluorescence and bottle chlorophyll-*a* collected from the pump in each sampling point.

Date [UTC]	Time [UTC]	Latitude	Longitude	Sensor Fluorescence	Chlorophyll- <i>a</i> (µg/L)
6-Jul-10	08:51	35°02.06'N	139°41.04'E	1.242	0.76
7-Jul-10	00:23	34°14.80'N	136°59.37'E	0.632	0.48
7-Jul-10	04:48	34°00.97'N	136°58.39'E	0.719	0.40
7-Jul-10	15:03	33°30.36'N	137°01.73'E	0.507	0.27
8-Jul-10	04:05	33°03.12'N	137°03.42'E	0.240	0.21
8-Jul-10	17:38	32°21.66'N	137°04.83'E	0.261	0.18
9-Jul-10	05:14	31°43.51'N	136°58.28'E	0.453	0.27
9-Jul-10	17:49	30°58.89'N	137°02.15'E	0.157	0.09
10-Jul-10	10:38	30°00.04'N	137°02.44'E	0.098	0.08
11-Jul-10	03:01	29°03.78'N	137°00.31'E	0.056	0.08
11-Jul-10	16:00	27°59.81'N	136°58.89'E	0.050	0.04
12-Jul-10	04:43	27°00.72'N	136°59.28'E	0.070	0.04
12-Jul-10	19:01	25°59.15'N	136°58.26'E	0.049	0.04
13-Jul-10	08:27	25°01.70'N	137°00.67'E	0.038	0.04
13-Jul-10	21:52	24°01.35'N	136°59.80'E	0.043	0.05
14-Jul-10	12:37	23°01.36'N	137°17.09'E	0.009	0.04
15-Jul-10	00:14	21°59.46'N	137°16.84'E	-0.004	0.05
15-Jul-10	13:39	21°00.03'N	136°55.59'E	0.025	0.03
16-Jul-10	01:15	19°57.38'N	136°59.99'E	0.029	0.05
16-Jul-10	13:25	18°59.38'N	136°58.47'E	0.086	0.07
17-Jul-10	03:10	18°00.68'N	137°02.40'E	0.050	0.07
17-Jul-10	17:16	17°00.64'N	136°55.61'E	0.127	0.07
18-Jul-10	06:56	16°00.56'N	136°57.81'E	0.129	0.08

18-Jul-10	18:48	14°58.61'N	136°58.13'E	0.183	0.07
19-Jul-10	08:19	13°59.99'N	136°57.16'E	0.145	0.06
19-Jul-10	21:45	12°59.91'N	136°57.25'E	0.193	0.06
20-Jul-10	11:13	12°00.11'N	136°56.43'E	0.151	0.03
21-Jul-10	01:28	11°00.56'N	136°56.68'E	0.212	0.06
21-Jul-10	14:50	10°00.13'N	136°58.09'E	0.242	0.04
22-Jul-10	02:57	9°00.78'N	136°57.52'E	0.229	0.06
22-Jul-10	17:19	7°59.83'N	136°58.61'E	0.339	0.06
23-Jul-10	14:29	7°00.36'N	136°58.13'E	0.510	0.05
2-Aug-10	02:38	7°01.80'N	136°59.66'E	0.105	0.10
4-Aug-10	11:23	3°45.89'N	140°14.74'E	-0.111	0.04
5-Aug-10	00:09	3°00.95'N	140°57.80'E	-0.104	0.06
5-Aug-10	17:49	1°59.73'N	141°58.66'E	-0.099	0.05
7-Aug-10	03:43	0°59.99'N	141°58.33'E	-0.024	0.09
7-Aug-10	12:11	0°29.74'N	141°57.93'E	-0.060	0.06
7-Aug-10	14:37	0°14.75'N	141°59.47'E	0.633	0.13
7-Aug-10	21:35	0°00.34'N	141°57.14'E	0.288	0.14
8-Aug-10	14:29	0°59.78'S	141°57.93'E	0.147	0.13
9-Aug-10	16:39	2°00.22'S	141°57.71'E	-0.033	0.14
10-Aug-10	22:56	1°58.91'N	141°59.16'E	-0.124	0.05
11-Aug-10	09:50	2°11.62'N	140°57.94'E	-0.101	0.05
11-Aug-10	22:08	2°24.47'N	139°58.34'E	-0.064	0.06
12-Aug-10	11:12	2°35.48'N	138°59.16'E	-0.071	0.05
13-Aug-10	01:37	2°47.76'N	137°59.88'E	-0.068	0.05
13-Aug-10	17:37	2°59.39'N	136°59.57'E	-0.009	0.07
14-Aug-10	09:46	4°00.91'N	136°57.92'E	-0.050	0.04
15-Aug-10	00:09	4°59.68'N	136°59.26'E	-0.014	0.06
15-Aug-10	18:15	5°58.61'N	136°56.93'E	-0.004	0.05
16-Aug-10	08:51	6°59.93'N	136°58.48'E	-0.009	0.04

Table B.5.3. Results of the fluorescence value of the sensor at the start and end of each leg(0 : deionized water, 10 : 0.1ppm Rhodamine solution).

	Start			End		
	Date [UTC]	0	10	Date [UTC]	0	10
1 Leg	6-Jul-10 08:30	0	10.000	27-Jul-10 05:00	0	8.296
2 Leg	1-Aug-10 04:30	0	10.000	20-Aug-10 01:32	0	8.438

6. *Acoustic Doppler Current Profiler*

(1) Personnel

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Takahiro SEGAWA (GEMD/JMA)

Yasuaki BUNGI (GEMD/JMA)

(2) Instruments and Methods

The instrument used was the hull-mounted 38kHz Ocean Surveyor ADCP (Teledyne RD Instruments, Inc., USA; hereafter TRDI). The transducer of the system was installed in a dome at 3 m left of center and 13 m aft of the bow at the water line. The firmware version was 23.17 and the data acquisition software was TRDI/VMDAS Version. 1.46. The instrument was used in water-tracking mode during the operations, and was recording each ping raw data in $20\text{ m} \times 60\text{ bin}$ from about 36 m to 1200 m in depth. Sampling interval was variable as short as possible and typically 6.4 seconds. GPS navigation data and ship's gyrocompass data were recorded with the ADCP data. In addition to the raw data, 60 seconds and 300 seconds averaged data were stored as short time average (STA) and long time average (LTA) data, respectively. Current field based on the gyrocompass was used to check the operation and the performance on board.

(3) Performance and quick view of the ADCP data on board

The performance of the ADCP instrument was almost good throughout the cruise, and current profiles were usually reached about 1000m. We monitored the profiles and currents based on LTA data in this cruise on board. The ADCP had been installed on the R/V Ryofu Maru just before the cruise, so the scale factor and misalignment angle (*Joyce*, 1989) to ADCP firmware for Leg 1 were set 1.0 and 0.0, respectively. The scale factor and misalignment for Leg 2 and Leg 3 were set 1.0012 and -1.0627 , respectively, based on the calibration constants evaluated

by the Leg 1 data.

(4) Data Processing

LTA data were processed by using CODAS (Common Oceanographic Data Access System) software, developed at the University of Hawaii (<http://currents.soest.hawaii.edu/docs/doc/index.html>). We use a standard CODAS processing including a PC time correction, a sound-speed correction based on the thermistor temperature at the transducers, and an amplitude and phase calibration constant applied to the measured velocities.

Calibration constants to be applied were evaluated for each leg using the water track data. For Leg 1, the amplitude and phase were 1.0012 and -1.0627 , respectively, and for Leg 2 and Leg 3, those were 1.0005 and -0.5528 , respectively. [Figure B.6.1](#) shows surface current at the depth of 36 m during the cruise.

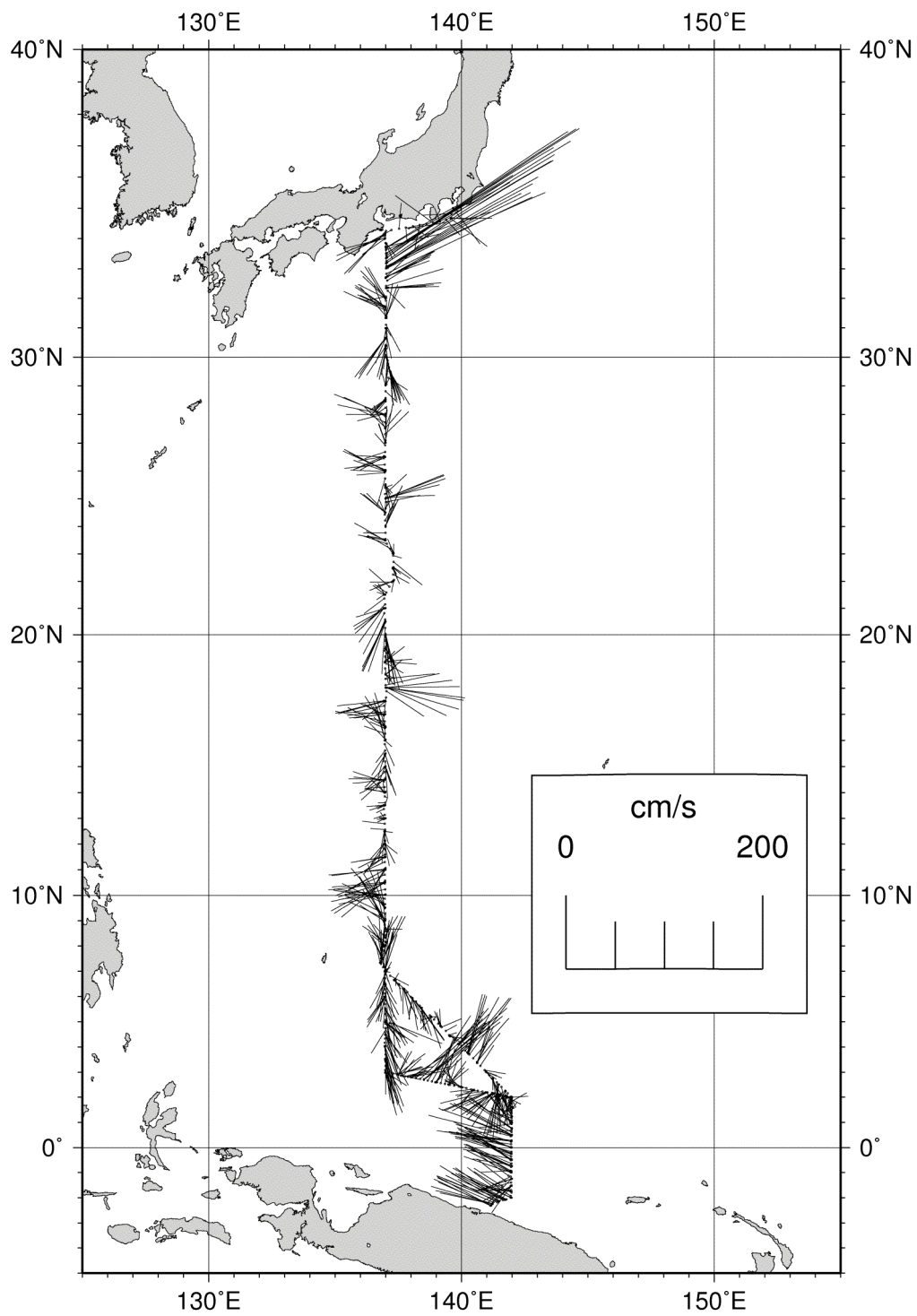


Figure B.6.1. Surface current at the depth of 36 m.

Reference

Joyce, T. M. (1988): On in-situ “calibration” of shipboard ADCPs. *J. Atmos. Oceanic Technol.*, **6**, 169-172.

C. Hydrographic Measurement Techniques and Calibration

1. CTD/O₂ Measurements

(1) Personnel

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Tomoyuki KITAMURA (GEMD/JMA)

Keizo SHUTTA (GEMD/JMA)

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(2) CTD Traction Winch and Motion Compensated Crane Arrangements

The CTD/O₂ system was deployed by using a Traction Winch System with ca. 7000 m of 8.03 mm armored cable (Tyco Electronics, USA) and a Motion Compensated Crane (Dynacon, Inc., USA). The system was installed on the *R/V Ryofu Maru* in March, 2010 (Photo C.1.1).



Photo C.1.1. (Left) The Traction Winch and (right) Motion Compensated Crane.

(3) Overview of the CTD/O₂ system

The CTD/O₂ system, SBE 911plus system (Sea-Bird Electronics, Inc., USA), was used for entire cruise. The system is consisted of a SBE 9plus underwater unit and a SBE 11plus deck unit. The SBE 11plus deck unit is a rack-mountable interface which supplies DC power to under water unit, decodes serial data stream, formats data under microprocessor control, and

passes the data to a computer. The real time serial data from the underwater unit is sent to the deck unit. The deck unit decodes the serial data and sends them to a personal computer to display and a storage in a file using SEASAVE data acquisition software (SEASAVE-Win32, version 7.18) .

The SBE 911plus system controls 36-position SBE 32 Carousel Water Sampler (Photo C.1.2). The Carousel with a custom frame accepts 10-liter Niskin bottles (General Oceanics, Inc., USA). The SBE 9plus was mounted horizontally in the 36-position carousel frame. Two set of SBE's temperature (SBE 3plus) and conductivity (SBE 4C) sensor modules were used with the SBE 9plus underwater unit. Two modular units of underwater housing pump (SBE 5T) flush water through sensor tubing at a constant rate independent of the CTD's motion (Photo C.1.3). Two dissolved oxygen sensors (RINKO III: JFE Advantech Co., Ltd., Japan; http://www.jfe-alec.co.jp/html/english_top.htm) were mounted on CTD housing, by the side of primary T/C sensors (Photo C.1.3). Auxiliary sensors, Deep Ocean Standards Thermometer (SBE 35) and an altimeter (PSA-916D: Teledyne Benthos, Inc., USA) were also used with the SBE 9plus underwater unit. The SBE 35 was mounted at the center of CTD between two pumps. The altimeter was mounted at the same height of pressure sensor of SBE 9plus.



Photo C.1.2. The CTD/O₂ system (left) top view and (right) bottom view.

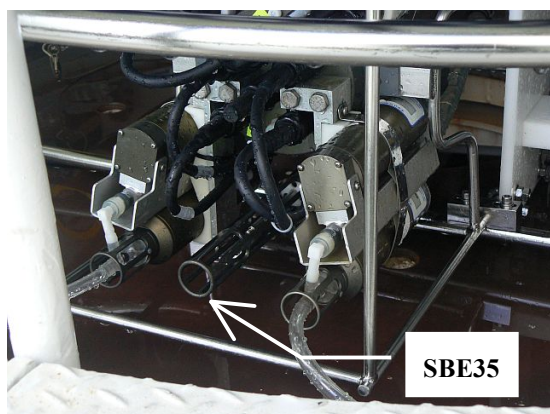


Photo C.1.3. (left) SBE 9plus CTD with SBE35 and (right) RINKO III.

Table C.1.1. Specification and serial number of the CTD/O₂ measurements system components.

<i>Deck unit</i>	<i>Serial Number</i>				
SBE 11plus (SBE)	0648				
<i>Under water unit</i>	<i>Serial Number</i>	<i>Range</i>	<i>Accuracy</i>	<i>Stability</i>	<i>Resolution</i>
SBE 9plus (SBE)	35560	0 to 10000 psi	0.015 % (FS)	0.002%FS/year	0.001 % (FS)
	(Pressure: 0764)	0 to 6800 dbar	1.0 dbar	0.2 dbar/year	0.1 dbar
<i>Temperature</i>	<i>Serial Number</i>	<i>Range</i>	<i>Accuracy</i>	<i>Stability</i>	<i>Resolution</i>
SBE 3plus (SBE)	4923 (primary)	-5 to 35 °C	0.001 °C	0.0002 °C/month	0.0002 °C
	4199 (secondary)				
<i>Conductivity</i>	<i>Serial Number</i>	<i>Range</i>	<i>Accuracy</i>	<i>Stability</i>	<i>Resolution</i>
SBE 4C (SBE)	3670 (primary)	0 to 7 S/m	0.0003 S/m	0.0003 S/m/month	0.00004 S/m
	2842 (secondary)				
<i>Pump</i>	<i>Serial Number</i>				
SBE 5T (SBE)	3887 (primary)				
	5501 (secondary)				

<i>Oxygen</i>	<i>Serial Number</i>	<i>Range</i>	<i>Linearity</i>	<i>Response time</i>	<i>Resolution</i>
RINKO III (JFE)	25 (primary, foil number:144) 26 (secondary, foil number:144)	0 to 200% (saturation)	±2% (FS)	≤1 second	0.01 to 0.04 %
<i>Water sampler</i>	<i>Serial Number</i>				
SBE 32 (SBE)	0734				
<i>Altimeter</i>	<i>Serial Number</i>	<i>Range</i>	<i>Resolution</i>		
PSA-916D (TB)	1267	0 to 100 m	1 cm		
<i>Water Sampling Bottle</i>					
Niskin Bottle (GO)	•10-Liter •No TEFRON coating	•Bottle O-ring: Viton •Stainless spring			

SBE: Sea-Bird Electronics Inc., USA JFE: JFE Advantech Co., Ltd., Japan

GO: General Oceanics, Inc., USA TB: Teledyne Benthos, Inc., USA

(4) Pre-cruise calibration

(4.1) Pressure

Pre-cruise calibration were performed at SBE, Inc., USA. The following coefficients were used in the SEASOFT:

S/N 0764, 25 May 2010

$$\begin{aligned}
 c_1 &= -4.318853e+04 \\
 c_2 &= -4.853949e-01 \\
 c_3 &= 1.294200e-02 \\
 d_1 &= 3.706500e-02 \\
 d_2 &= 0.000000e+00 \\
 t_1 &= 3.005385e+01 \\
 t_2 &= -4.407111e-04 \\
 t_3 &= 4.098190e-06 \\
 t_4 &= 1.662250e-09
 \end{aligned}$$

$$t_5 = 0.000000e+00$$

Pressure coefficients are formulated into

$$\begin{aligned} c &= c_1 + c_2 \times U + c_3 \times U^2 \\ d &= d_1 + d_2 \times U \\ t_0 &= t_1 + t_2 \times U + t_3 \times U^2 + t_4 \times U^3 + t_5 \times U^4 \end{aligned}$$

where U is temperature in degrees Celsius. The pressure temperature, U, is determined according to

$$U(\text{degrees Celsius}) = M \times (12 \text{ bit pressure temperature compensation word}) - B$$

The following coefficients were used for S/N 0764 in SEASOFT:

$$\begin{aligned} M &= 1.289080e-02 \\ B &= -8.282450e+00 \end{aligned}$$

(in the underwater unit system configuration sheet dated on 25 May, 2010)

Finally, pressure is computed as

$$P(\text{psi}) = c \times (1 - t_0^2/t^2) \times \left\{ -d \times (1 - t_0^2/t^2) \right\}$$

where t is pressure period (μsec).

Since the pressure sensor measures the absolute value, it inherently includes atmospheric pressure (about 14.7 psi). SEASOFT subtracts 14.7 psi from computed pressure above automatically.

The pressure sensor drift is known to be primarily an offset drift at all pressures rather than a change of span slope. The following coefficients for the sensor drift correction were also used in SEASOFT:

$$\begin{aligned} &S/N 0764, 25 May 2010 \\ &Slope = 0.999930 \\ &Offset = -0.56680 \end{aligned}$$

The drift-corrected pressure is computed as

$$\text{Drift corrected pressure (dbar)} = \text{slope} \times (\text{computed pressure in dbar}) + \text{offset}$$

(4.2) Temperature (SBE 3plus)

(4.2) Temperature (SBE 3plus)

Pre-cruise calibrations were performed at SBE, Inc., USA. The following coefficients were used in SEASOFT:

S/N 4923(primary), 26 May 2010

$$g = 4.35306322\text{e-}03$$

$$h = 6.39215989\text{e-}04$$

$$i = 2.11728148\text{e-}05$$

$$j = 1.77647263\text{e-}06$$

$$f_0 = 1000.000$$

S/N 4199(secondary), 26 May 2010

$$g = 4.39450115\text{e-}03$$

$$h = 6.49623486\text{e-}04$$

$$i = 2.38724882\text{e-}05$$

$$j = 2.21735485\text{e-}06$$

$$f_0 = 1000.000$$

Temperature (ITS-90) is computed according to

$$Temperature(ITS - 90) = \frac{1}{g + h \times \ln(f_0/f) + i \times \ln^2(f_0/f) + j \times \ln^3(f_0/f)} - 273.15$$

where f is the instrument frequency (Hz).

Time drift of the SBE 3plus temperature sensors based on the laboratory calibrations is shown in [Figure C.1.1](#).

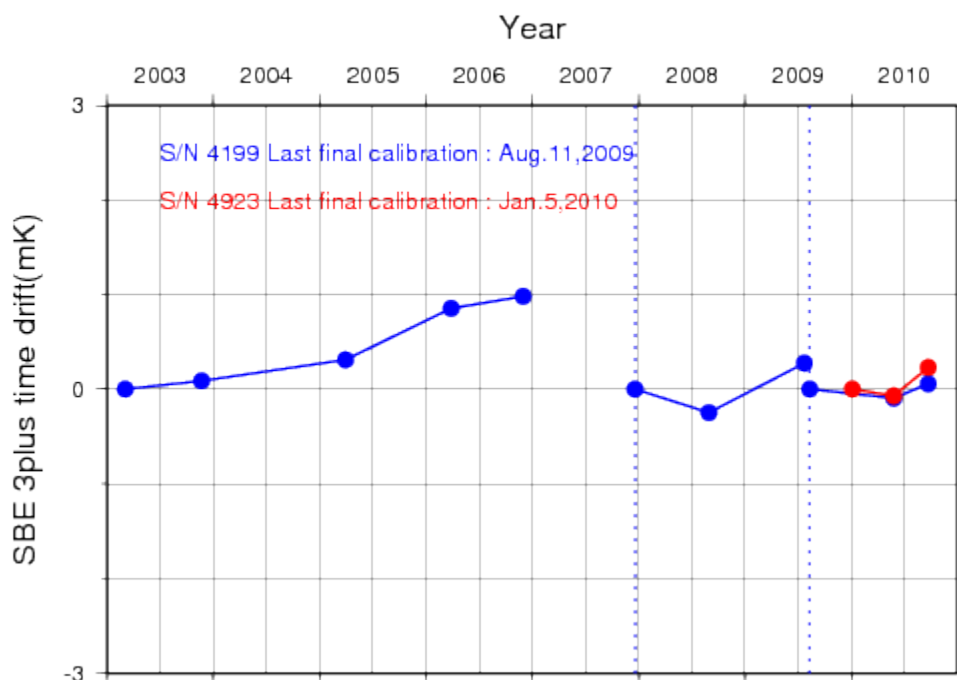


Figure C.1.1. Time drift of the SBE 3plus temperature sensors (S/N 4923 and 4199) based on laboratory calibrations performed by SBE, Inc. The secondary sensor (S/N4199) was resecured the temperature probe retaining nut in December 2007, and replaced the main piston O-rings in August 2009

(4.3) Conductivity (SBE 4C)

Pre-cruise sensor calibrations were performed at SBE, Inc., USA. The following coefficients were used in SEASOFT:

S/N 3670(primary), 26 May 2010

$$\begin{aligned}
 g &= -1.02022781e+001 \\
 h &= 1.57745207e+000 \\
 i &= -2.48735605e-003 \\
 j &= 2.86313468e-004 \\
 CP_{cor} &= -9.57e-08 \\
 CT_{cor} &= 3.25e-06
 \end{aligned}$$

S/N 2842(secondary), 26 May 2010

$$\begin{aligned}g &= -1.01321263\text{e}+001 \\h &= 1.38952824\text{e}+000 \\i &= 2.52094473\text{e}-004 \\j &= 4.58018677\text{e}-005 \\CP_{cor} &= -9.57\text{e}-08 \\CT_{cor} &= 3.25\text{e}-06\end{aligned}$$

Conductivity of a fluid in the cell is expressed as:

$$C(S/m) = (g + h \times f^2 + i \times f^3 + j \times f^4) \{10 \times (1 + CT_{cor} \times t + CP_{cor} \times p)\}$$

where f is the instrument frequency (kHz), t is the water temperature (degrees Celsius) and p is the water pressure (dbar).

(4.4) Deep Ocean Standards Thermometer (SBE 35)

In the first place, a newly manufactured SBE 35 is first calibrated in a temperature controlled bath against Standard Platinum Resistance Thermometer, and this calibration is referred as the Linearization Calibration. In the next place SBE 35 is calibrated to generate slope and offset coefficients that correct for the time drift from the Linearization Calibration. This calibration is referred as the Fixed Point Calibrations. Pre-cruise sensor calibrations were performed at SBE, Inc., USA. The following coefficients were stored in EEPROM:

S/N 0069, 23 October 2006(1st step: Linearization Calibration)

$$\begin{aligned}a_0 &= 4.96812728\text{e}-003 \\a_1 &= -1.39341438\text{e}-003 \\a_2 &= 2.06596098\text{e}-004 \\a_3 &= -1.14827915\text{e}-005 \\a_4 &= 2.44200422\text{e}-007\end{aligned}$$

Linearized temperature (ITS-90) is computed according to

$$\text{Linearized temperature(ITS-90)} = 1/\{a_0 + a_1 \times \ln(n) + a_2 \times \ln^2(n) + a_3 \times \ln^3(n) + a_4 \times \ln^4(n)\} + 273.15$$

where n is the instrument output. Then the SBE 35 is certified by measurements in thermodynamic fixed-point cells of the Triple Point of Water (TPW: 0.0100 degrees Celsius) and Gallium Melting Point (GaMP: 29.7646 degrees Celsius). The slow time drift of the SBE 35 is adjusted by periodic recertification corrections.

S/N 0069, 21 August 2009 (2nd step: Fixed Point Calibration)

Slope=0.999998

Offset=0.000258

Temperature (ITS-90) is calibrated according to

$$Temperature(ITS-90) = slope * (Linearized\ temperature) + offset$$

The time required per sample = 1.1 * NCYCLES + 2.7 seconds. The 1.1 seconds is total time per an acquisition cycle. NCYCLES is the number of acquisition cycles per sample. The 2.7 seconds is required for converting the measured values to temperature and storing average in EEPROM. In this cruise NCYCLES was set to 2.

(5) Data processing

(5.1) Data Collection

CTD system was powered on at least five minutes in advance of the operation and was powered off after CTD came up from the surface.

The package was lowered into the water from the port side and held about 10 m beneath the surface for about one minute in order to activate the pump. After the pump was activated, the package was lifted to the surface and lowered at a rate of 0.6 m/s approximately to 50 m depth (or more when wave height was high), then the package was stopped to turn on the heave compensator of the crane. The package was lowered again at a rate of 0.9 m/s to the bottom. For the up cast, the package was lifted at a rate of 0.9 m/s except for bottle firing stops. At each bottle firing stops, the bottle was fired after waiting for about 30 seconds and the package was stayed at least 10 seconds for measurement of the SBE 35 after firing. At 50 m depth from the surface, the package was stopped to turn off the heave compensator of the crane.

Water samples were collected using a 36-position SBE 32 Carousel Water Sampler with 10-liter Niskin bottles. In addition, surface water was sampled by stainless steel buckets when the CTD package was lifted to about 300 m depth.

The SBE11plus deck unit received the data signal from the CTD. Digitized data were forwarded to a personal computer running the SEASAVE data acquisition software (*SEASAVE-Win32, version 7.18*). Temperature, conductivity, salinity, oxygen and descent/ascent rate profiles were displayed in real-time with the package depth, altimeter reading and sound speed. Differences in temperature, salinity, and oxygen between primary and secondary sensor were also displayed in order to monitor the status of sensors. Note that oxygen data were displayed and monitored in voltage (0 - 5 V).

Altimeter (PSA-916D) was mounted at the same height of pressure sensor of SBE 9plus (Photo C.1.4). The altimeter detected the sea floor at 100 of 124 stations. The average distance from the sea floor at the beginning of the detection was 26.4 m, and the average distance from the sea floor at the closest in each station was 13.8m. The summary of sea floor detection of PSA-916D was shown in [Figure C.1.2](#).

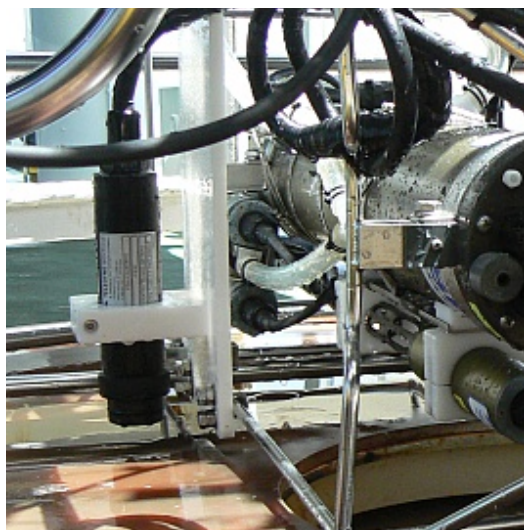


Photo C.14. The location of PSA-916D.

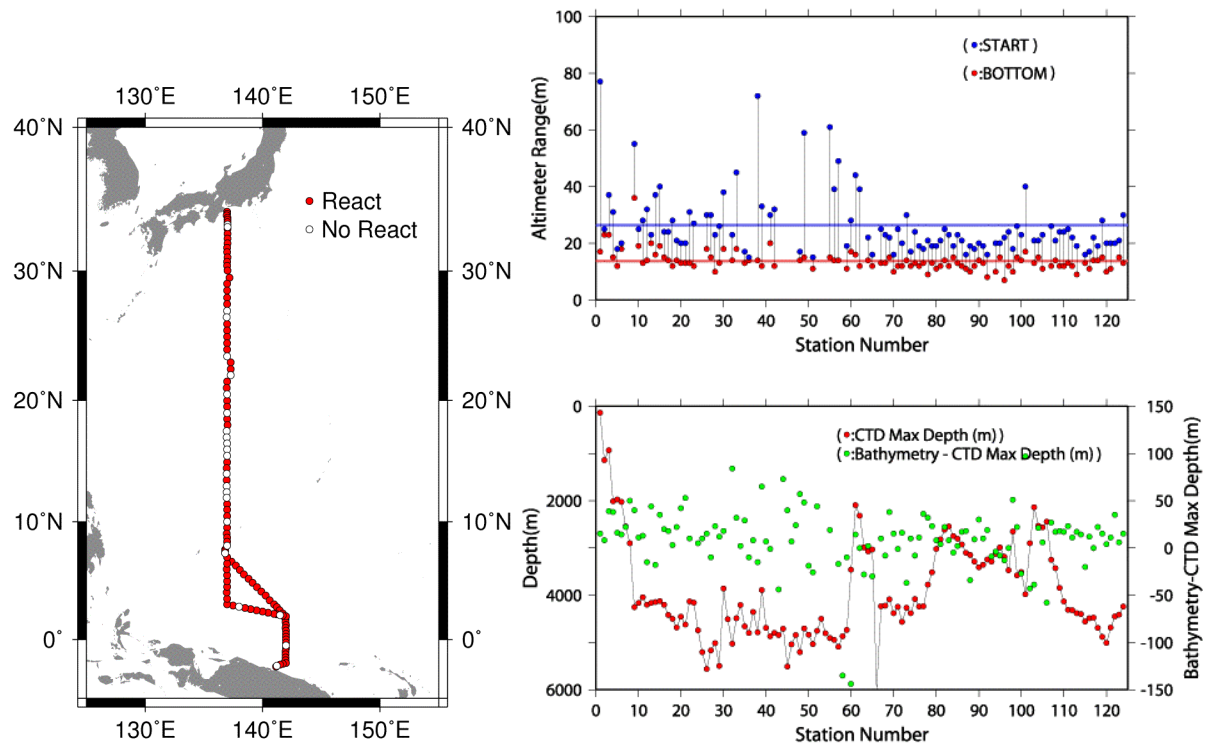


Figure C.1.2. The summary of detection of PSA-916D. The left panel shows the stations of detection, the right panel shows the relationship among PSA-916D, bathymetry and CTD depth.

(5.2) Data Processing

SEASOFT (*SEASOFT-Win32, version 7.18*) consists of modular menu driven routines for acquisition, display, processing, and archiving of oceanographic data acquired with SBE equipment, and is designed to work with a personal computer. Raw data are acquired from instruments and are stored as unmodified data. The conversion module ***DATCNV*** uses instrument configuration and calibration coefficients to create a converted engineering unit data file that is operated on by all SEASOFT post processing modules.

Each SEASOFT module that modifies the converted data file adds proper information to the header of the converted file permitting tracking of how the various oceanographic parameters were obtained. The converted data is stored in rows and columns of ASCII numbers. The last data column is a flag field used to mark scans as good or bad.

We developed some original module for the process of RINKO III oxygen sensor and other

data treatment. The followings are the SEASOFT data processing module and JMA original module sequence and specifications used in the reduction of CTD data in this cruise.

DATCNV converted the raw data to engineering unit data such as scan number, pressure, temperatures, conductivities, RINKO III voltages, time in Julian days, pump status, and flag. ***DATCNV*** also extracted bottle information where scans were marked with the bottle confirm bit during acquisition. The duration was set to 2.0 seconds, and the offset was set to 0.0 seconds.

DECKP_OFF (original module) cancelled the deck pressure. After this module applied, spikes in temperature and salinity were eliminated manually.

RINKO_hystoff (original module) cancelled the pressure hysteresis of RINKO III using the same method of SBE 43 (*Sea-Bird Electronics*, 2009).

SECT_IN (original module) found the first and last scan numbers while pump was activated, and made the surface data while pump was not activated for down cast.

SECTION selected a time span of data based on scan number in order to reduce a file size. The minimum number was set to be the start time when the CTD package was beneath the sea-surface after activation of the pump. The maximum number was set to be the end time when the package came up from the surface.

FILTER performed a low pass filter on pressure with a time constant of 0.15 seconds. In order to produce zero phase lag (no time shift) the filter runs forward first then backwards.

ALIGNCTD converted the time-sequence of RINKO III sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. RINKO III sensor output delays 1 second compared to pressure, temperature and conductivity.

ALIGNROS (original module) replace the RINKO III output of the bottle to that of all scan data applied **ALIGNCTD** module.

BOTTOLESUM created a summary of the bottle data. The bottle position, date, time were output as the first two columns. Salinities, pressure, temperatures, conductivities and oxygen voltage were averaged over 2.0 seconds.

CELLTM used a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. Typical values used were thermal anomaly amplitude $\alpha = 0.03$ and the time constant $1/\beta = 7.0$.

LOOPEDIT marked scans where the CTD was moving less than the minimum velocity of 0.0 m/s (traveling backwards due to ship roll).

BINAVG averaged the data into 1 dbar pressure bins. The center value of the first bin was set equal to the bin size. The bin minimum and maximum values are the center value plus and minus half the bin size. Scans with pressures greater than the minimum and less than or equal to the maximum were averaged. Scans were interpolated so that a data record could exist in every dbar.

(6) Post-cruise calibration

(6.1) Pressure

The CTD pressure sensor offset in the period of this cruise is estimated from the pressure readings on the ship deck. In order to get the calibration data for the pre-cast pressure sensor drift, the CTD deck pressure was averaged over five scan pressure data after the CTD system had been stable on the deck.

Deck pressure was used to cancel the CTD pressure sensor offset in CTD data processing. Time series of the CTD deck pressure is shown in [Figure C.1.3](#). Tendencies of CTD deck

pressure and air pressure were almost similar during the cruise.

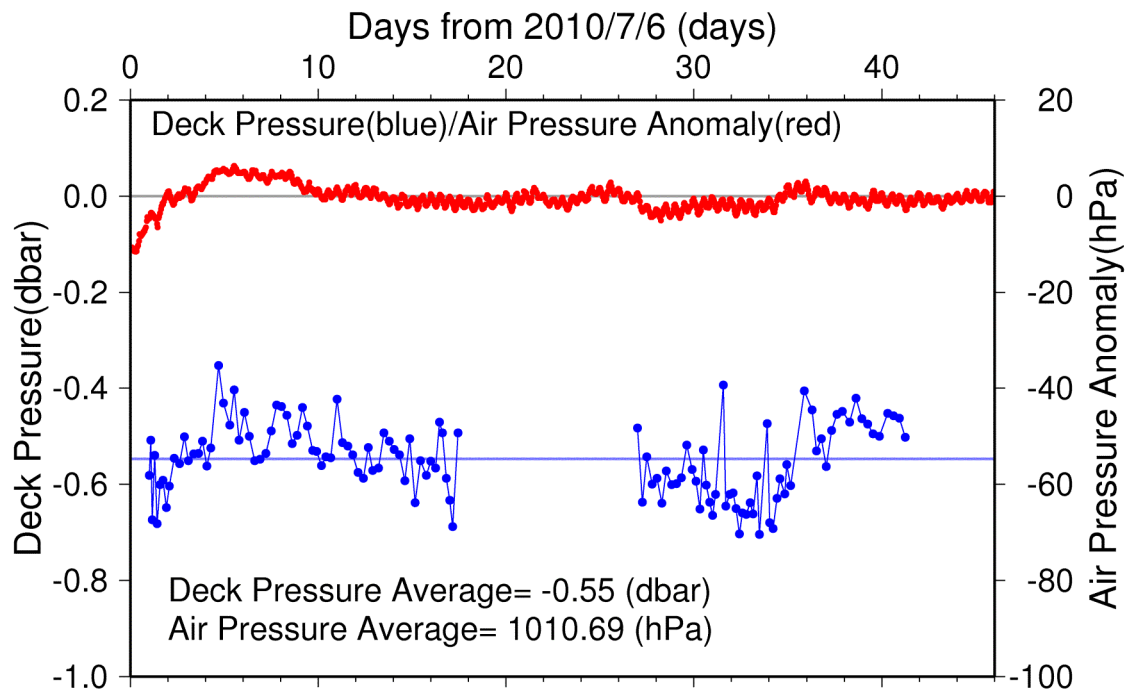


Figure C.1.3. Time series of the CTD deck pressure. Red line indicates atmospheric pressure anomaly. Blue line and dots indicate pre-cast deck pressure and average.

Post-cruise sensor calibrations were performed at SBE, Inc., USA. The pressure sensor drift is known to be primarily an offset drift at all pressures rather than a change of span slope.

S/N 0764, 27 September 2010

$$\text{Slope} = 0.999940$$

$$\text{Offset} = -0.55550$$

The pressure sensor drift was estimated to be 0.07 dbar at the pressure of 6000 dbar. The pressure sensor drift was small, so post-cruise calibration is not applied.

(6.2) Temperature

Budeus and Schneider (1998) noted that the CTD temperature sensor (SBE 3plus) showed a pressure sensitivity. The pressure sensitivity for a SBE 3plus sensor is usually less than +2 mK/6000 dbar. It is somewhat difficult to measure this effect in the laboratory and the difficulty is one of the primary reasons to use the SBE 35 at sea for critical work. Also SBE

3plus measurements may be affected by viscous heating (about +0.5 mK) that occurs in a TC duct and does not occur for un-pumped SBE 35 measurements (*Larson and Pederson, 1996*). Furthermore, the SBE 35 calibrations have some uncertainty (about 0.2 mK) and SBE 3plus calibrations have some uncertainty (about 1 mK). So the practical corrections for CTD temperature data can be made by using a SBE 35, correcting the SBE 3plus to agree with the SBE 35 (*Uchida et al., 2007*).

Post-cruise sensor calibration for the SBE 35 was performed at SBE, Inc., USA.

S/N 0069, 03 October 2010 (2nd step: fixed point calibration)

$$\text{Slope}=1.000009$$

$$\text{Offset}=0.000313$$

The discrepancy between the CTD temperature and the SBE 35 temperature is considered to be a function of pressure and time. But the time drift correction is regarded as 0 due to following reasons; 1) The time drift of the SBE 3plus estimated to be as -0.00094 K/year for S/N 4923, -0.00044 K/year for S/N 4199 and that of SBE 35 is estimated to be as $+0.01$ mK during cruise according to pre-cruise and post-cruise calibrations performed at SBE, 2). Effect of the viscous heating is assumed to be constant. Since the pressure sensitivity is thought to be constant in time at least during observation period, the CTD temperature is calibrated as

$$\text{Calibrated temperature} = T - (c_0 + c_1 \times P)$$

where T is the CTD temperature in degrees Celsius, P is pressure in dbar and c_0 , c_1 are calibration coefficients.

The calibration is performed for the primary and secondary temperature data. The CTD data created by the software module **BOTTLESUM** are used. (The deviation of CTD temperature from the SBE35 temperature at depth shallower than 1900 dbar is large for determining the coefficients with sufficient accuracy since the vertical temperature gradient is too large in the regions. So the coefficients are determined by least squares method using the data for the depth deeper than 1900 dbar. The temperature calibration summary is listed in [Table C.1.1](#) for Pressure ≥ 1900 dbar. We adopted secondary conductivity sensor (S/N 2842) as described in subsection (6.3), so secondary temperature sensor (S/N4199) is adopted.

Table C.1.1. Temperature Calibration summary (Pressure ≥ 1900 dbar).

S/N	Num	c_0 (K)	c_1 (K/dbar)	Average (K)	STD (K)	Note
4923	620	5.2348920e-4	2.3591956e-7	0.0000	0.0002	Leg 1
4923	378	5.8598217e-4	2.3668426e-7	0.0000	0.0002	Leg 2
4199	620	2.0889685e-4	2.4549467e-7	0.0000	0.0002	Leg 1
4199	378	2.3835674e-4	2.3980066e-7	0.0000	0.0002	Leg 2

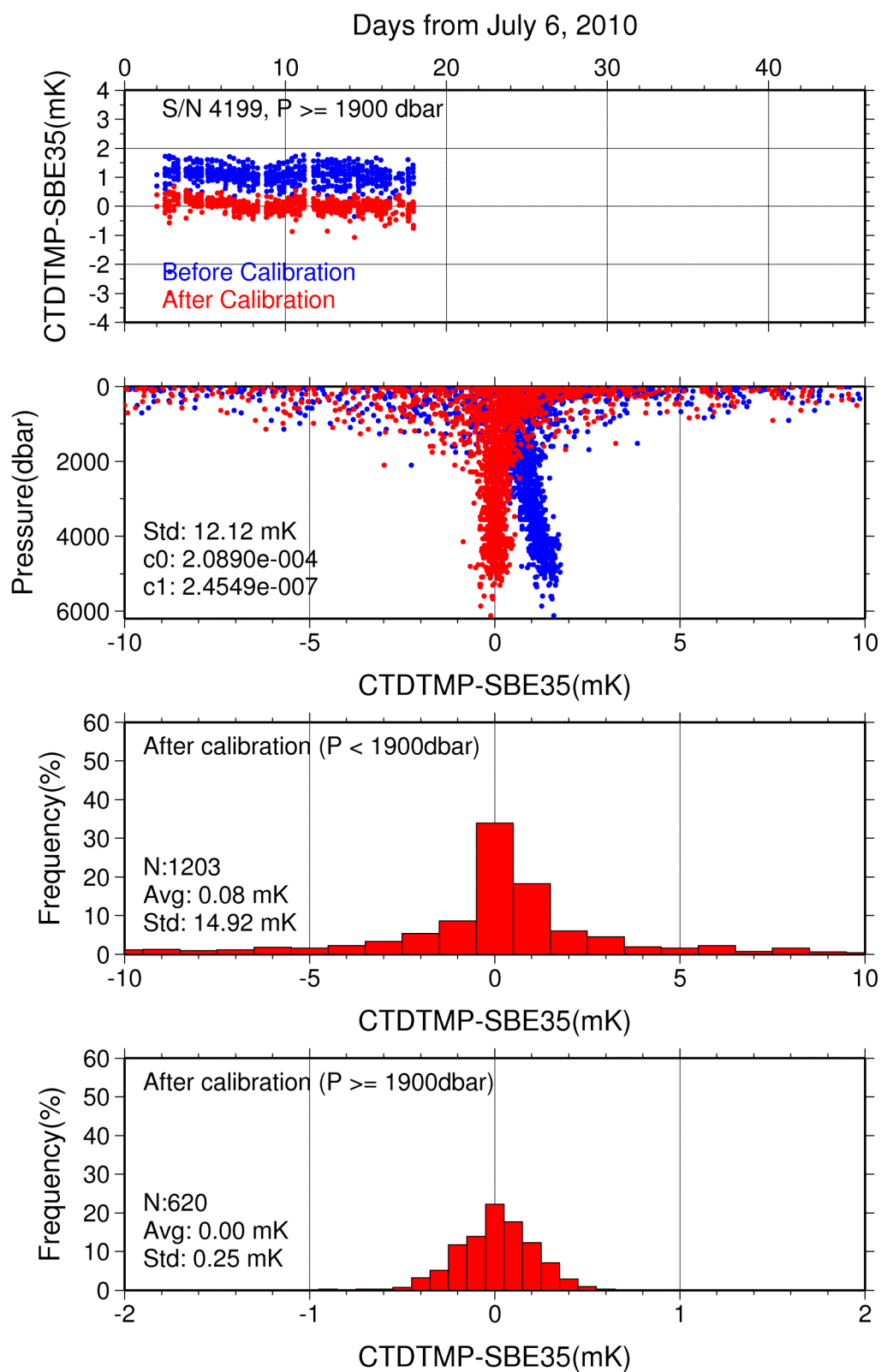


Figure C.1.4. Difference between the CTD temperature (secondary) and the Deep Ocean Standards thermometer (SBE35) at Leg 1. Blue and red dots indicate before and after the calibration using SBE35 data respectively. Lower two panels show histogram of the difference after calibration.

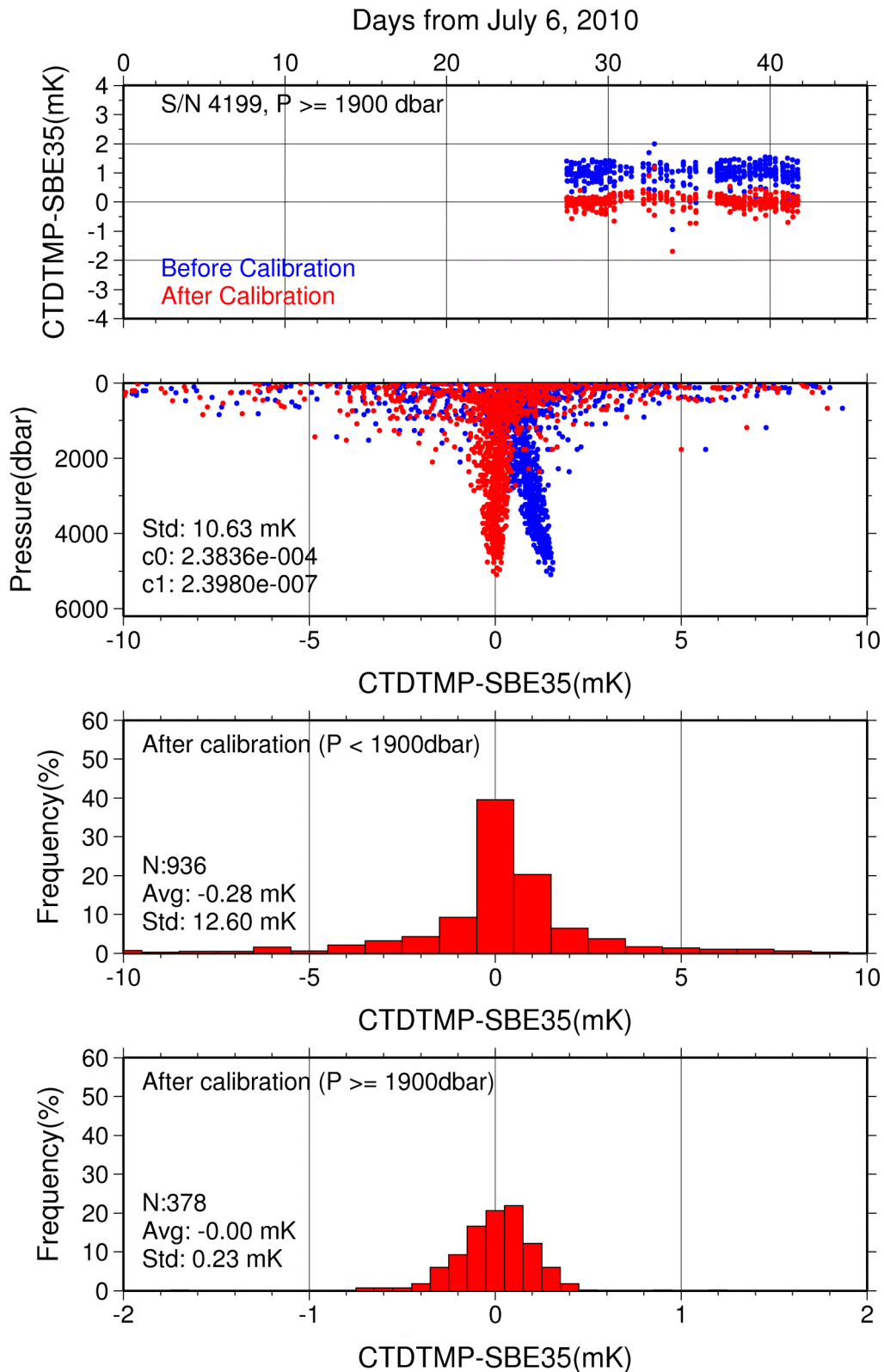


Figure C.1.5. Difference between the CTD temperature (secondary) and the Deep Ocean Standards thermometer (SBE35) at Leg 2. Blue and red dots indicate before and after the calibration using SBE35 data respectively. Lower two panels show histogram of the difference after calibration.

(6.3) Salinity

The CTD salinity is computed from pressure, conductivity and temperature according to algorithm of the Practical Salinity Scale of 1978 (PSS78). The discrepancy between the CTD conductivity and the bottle conductivity is considered to be a function of pressure and time (*McTaggart et al*, 2010).

Post-cruise sensor calibrations were performed in September 2010 at SBE, Inc., USA. According to the conductivity calibration report, the drifts since pre-cruise calibration was -0.00090 /month in PSS78 at 3.0 S/m for primary sensor (S/N3670), so the effect of SBE 4C drift during the cruise was estimated to be less than 0.002 in PSS78. However the time coefficient was set to zero in this cruise because the calibration with bottle salinity was performed considering the sudden station-dependent shifts of the CTD conductivity and other calibration coefficients included the effect of slow drift by calibration grouping. So the CTD conductivity is calibrated as below.

$$\text{Calibrated Conductivity} = C - \left(\sum_{i=0}^I c_i \times C^i + \sum_{j=1}^J p_j \times P^j \right)$$

where C is the CTD conductivity and c_i and p_j are calibration coefficients. Coefficient sets of each (I, J) combination was calculated by least square method between CTD conductivity and the bottle conductivity data except for bad bottle data. In calculated coefficient sets, the best (I, J) combination are determined by referring to AIC (*Akaike*, 1974). According to *McTaggart et al*. (2010), maximum of I and J are 2.

The discrepancy between the calibrated CTD conductivity and the bottle conductivity was within 0.0001 S/m for each sensor. The results of post-cruise calibration for the CTD salinity (S/N 2849) are summarized in [Figure C.1.6](#). The calibration coefficients and the data (Num) used for the calibration are listed in [Table C.1.2](#), and the calibration summary are listed in [Table C.1.3](#) and [C.1.4](#) for S/N 3670 and S/N 2842, respectively. Secondary sensor (S/N 2842) is adopted because of large time drift of primary sensor (S/N 3670).

Table C.1.2. Conductivity Calibration Coefficient Summary.

S/N	Num	$c_0(\text{mS/m})$	c_1	$c_2(\text{mS/m})$	Stations
			$p_1(\text{mS/dbar})$	$p_2(\text{mS/m/dbar}^2)$	
3670	1274	1.5107e-3	-7.4144e-5	0.0000e+0	Stn. 1 – 67
			6.6856e-7	-8.3866e-11	
3670	308	2.2680e-3	-8.0696e-5	0.0000e+0	Stn. 68 – 83,
			-1.2437e-8	0.5038e-11	Stn. 105 – 107
3670	608	1.0048e-3	-7.6991e-5	0.0000e+0	Stn. 84 – 104,
			3.9031e-7	-4.2466e-11	Stn. 108 – 124
2849	2195	2.1693e-3	-5.5359e-5	0.0000e+0	Stn. 1 – 124
			8.3709e-7	-7.6495e-11	

Table C.1.3. Conductivity Calibration Summary for S/N 3670.

Stations	Pressure < 1900dbar			Pressure \geq 1900 dbar		
	Num	Average (mS/cm)	Std (mS/cm)	Num	Average (mS/cm)	Std (mS/cm)
Stn. 1 – 67	830	0.0000	0.0022	444	-0.0000	0.0006
Stn. 68 – 83, 105 – 107	211	0.0000	0.0024	94	0.0000	0.0004
Stn. 84 – 104, 108 – 124	411	0.0000	0.0023	197	-0.0000	0.0005

Table C.1.4. Conductivity Calibration Summary for S/N 2842.

Stations	Pressure < 1900dbar			Pressure \geq 1900 dbar		
	Num	Average(mS/cm)	Std(mS/cm)	Num	Average(mS/cm)	Std(mS/cm)
Stn. 1 – 124	1455	0.0000	0.0022	740	-0.0000	0.0004

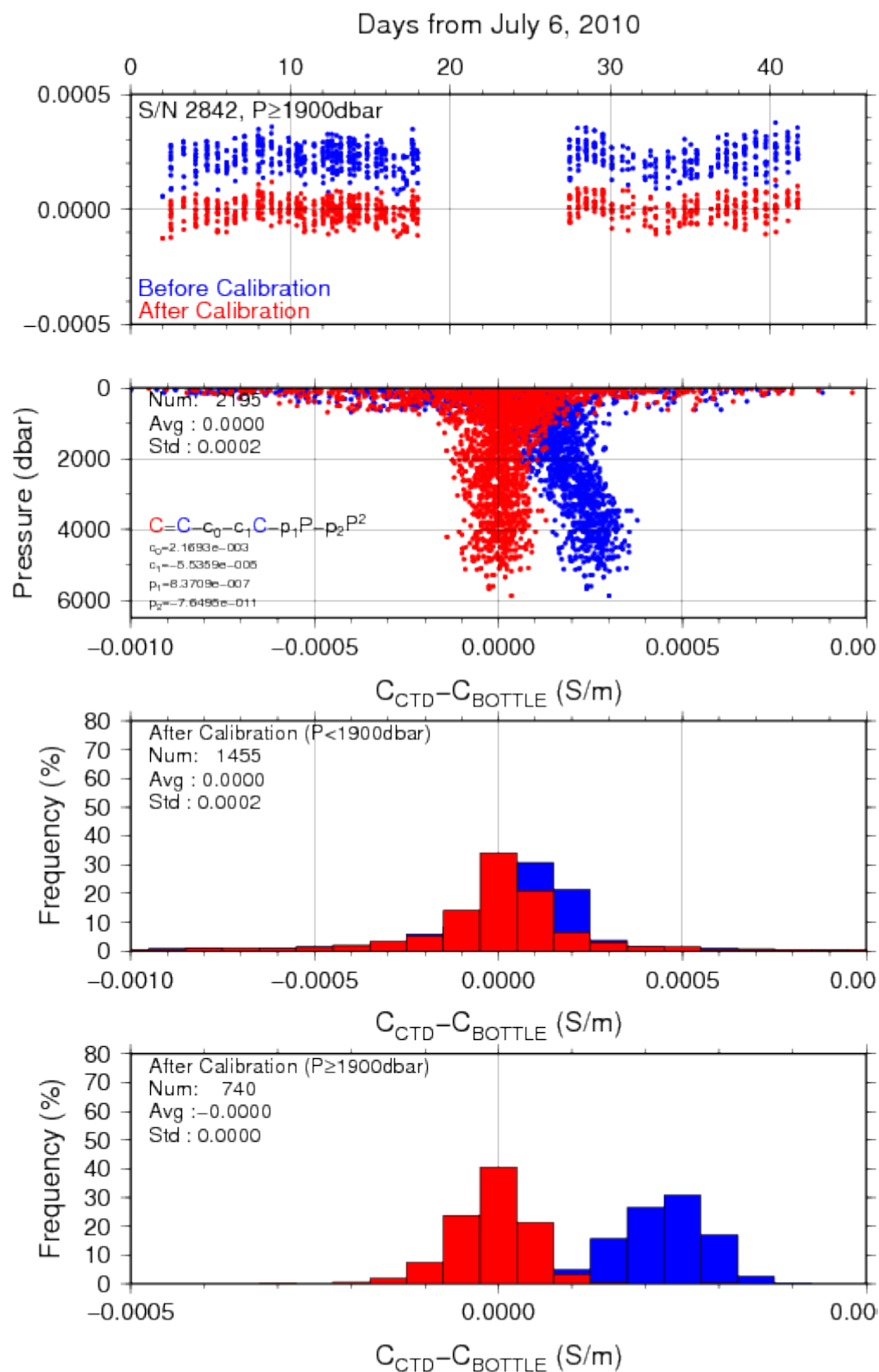


Figure C.1.6. Difference between the CTD conductivity (secondary) and the bottle conductivity. Blue and red dots indicate before and after the calibration using bottle data respectively. Lower two panels show histogram of the difference before and after calibration.

(6.4) Oxygen

RINKO III (JFE Advantech Co., Ltd., Japan) is based on the ability of selected substance to act as dynamic fluorescence quenchers. RINKO III model is designed to use with a CTD system which accept an auxiliary analog sensor, and is designed to operate down to 7000 m. The CTD oxygen is calculated using RINKO III output (voltage) by the Stern-Volmer equation, according to a method by *Uchida et al.* (2008). The formulas are as follows:

$$\begin{aligned}P_0 &= 1.0 + c_4 \times t \\P_c &= c_5 + c_6 \times v + c_7 \times T + c_8 \times T \times v \\K_{sv} &= c_1 + c_2 \times t + c_3 \times t^2 \\coef &= (1.0 + c_9 \times P/1000)^{1/3} \\[O_2] &= \{(P_0 / P_c - 1.0) / K_{sv} \times coef\}\end{aligned}$$

Where ***P*** is the pressure in dbar, ***t*** is the potential temperature, ***v*** is RINKO III output voltage in volt, ***T*** is elapsed time of the sensor from the beginning of first station in calculation group in day and ***[O₂]*** is the dissolved oxygen saturation, dissolved oxygen is calculated from ***[O₂]***, ***potential temperature*** and ***salinity*** by *Garcia and Gordon* (1992) in $\mu\text{mol/kg}$. Calibration coefficients (c_1 – c_9) are determined by minimizing difference between CTD oxygen and bottle dissolved oxygen by quasi-newton method (*Shanno*, 1970).

In general, the calibration was performed for each Leg. But in this cruise, both RINKO III had large time drift especially in the early part of Leg 1, we could not solve on c_7 and c_8 . Worse yet, bottle dissolved oxygen data were flagged bad due to the problem of titration (please refer to section C.3. (15)) in the latter part of Leg1 (Stn. 58 - 67). To avoid extrapolation in time during the period when bottle dissolved oxygen data were flagged bad, the calibration was performed across Leg 1 and Leg 2. The calibration was performed only for primary sensor (S/N 25, foil number: 144) because the output of secondary sensor (S/N 26 foil number: 144) was very noisy during the entire cruise. Calibration coefficients are listed in [Table C.1.5](#). The result of the calibration during cruise is shown in [Figure C.1.7](#), the data summary is listed in [Table C.1.6](#) and [Table C.1.7](#).

Table C.1.5. Dissolved Oxygen Calibration Coefficients.

Stations	c ₁	c ₂	c ₃	c ₄	c ₅
	c ₆	c ₇	c ₈	c ₉	
Stn. 1 – 29	1.89890	1.71137e-2	1.59838e-4	-1.07941e-3	-1.23152e-1
	3.06114e-1	-4.58703e-5	9.88747e-4	4.50828e-2	
Stn. 30 – 80	1.92314	2.01695e-2	1.61815e-4	-8.26530e-4	-1.29883e-1
	3.08780e-1	-5.98333e-4	8.81185e-4	4.21446e-2	
Stn. 81 – 124	1.78777	1.54077e-2	1.57742e-5	-1.66459e-3	-1.02899e-1
	3.06817e-1	9.27247e-5	4.29204e-4	4.59279e-2	

Table C.1.6. Dissolved Oxygen Calibration Summary.

Stations	Pressure < 950dbar			Pressure ≥ 950dbar		
	Num	Average of deviation (μmol/kg)	STD of deviation (μmol/kg)	Num	Average of deviation (μmol/kg)	STD of deviation (μmol/kg)
Stn. 1 – 29	228	-0.26	0.97	218	-0.07	0.34
Stn. 30 – 80	446	-0.02	0.83	422	0.00	0.22
Stn. 81 – 124	435	-0.04	0.77	308	-0.01	0.25

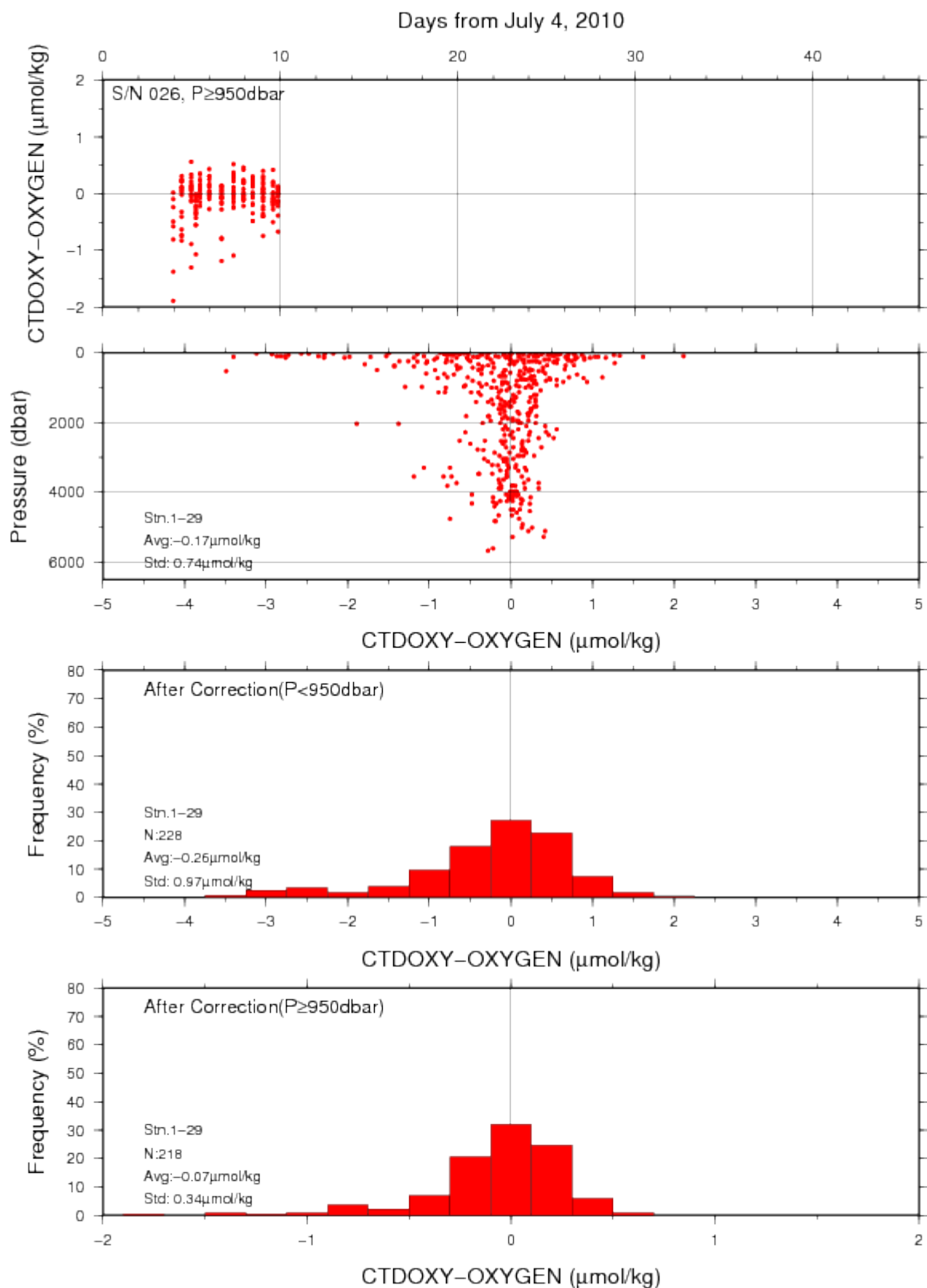


Figure C.1.7. Difference between the CTD oxygen and bottle dissolved oxygen in the early part of Leg 1. Red dots in upper two panels indicate the result of calibration. Lower two panels show histogram of the difference between calibrated oxygen and bottle oxygen.

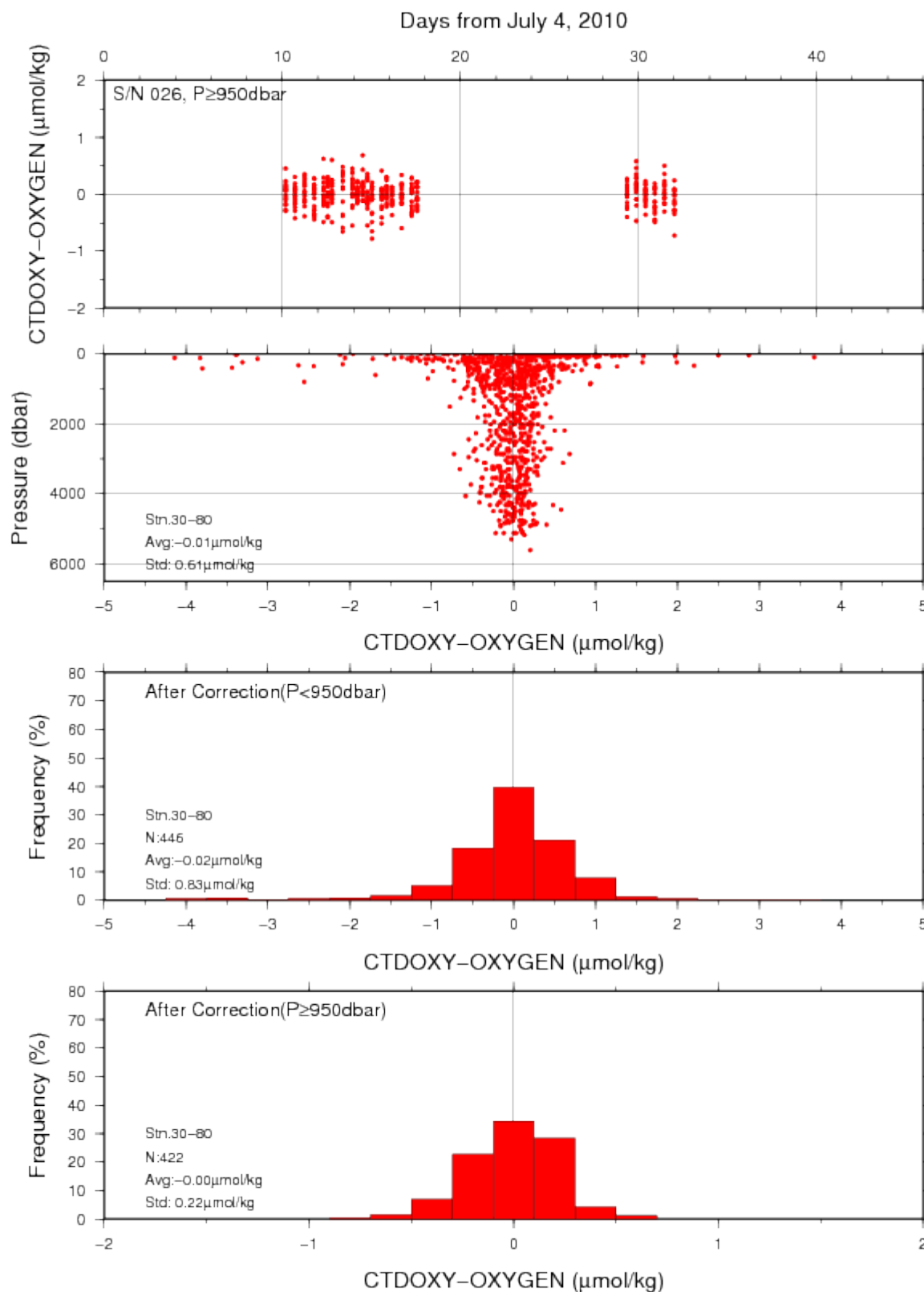


Figure C.1.8. Difference between the CTD oxygen and bottle dissolved oxygen across Leg 1 and Leg 2. Red dots in upper two panels indicate the result of calibration. Lower two panels show histogram of the difference between calibrated oxygen and bottle oxygen.

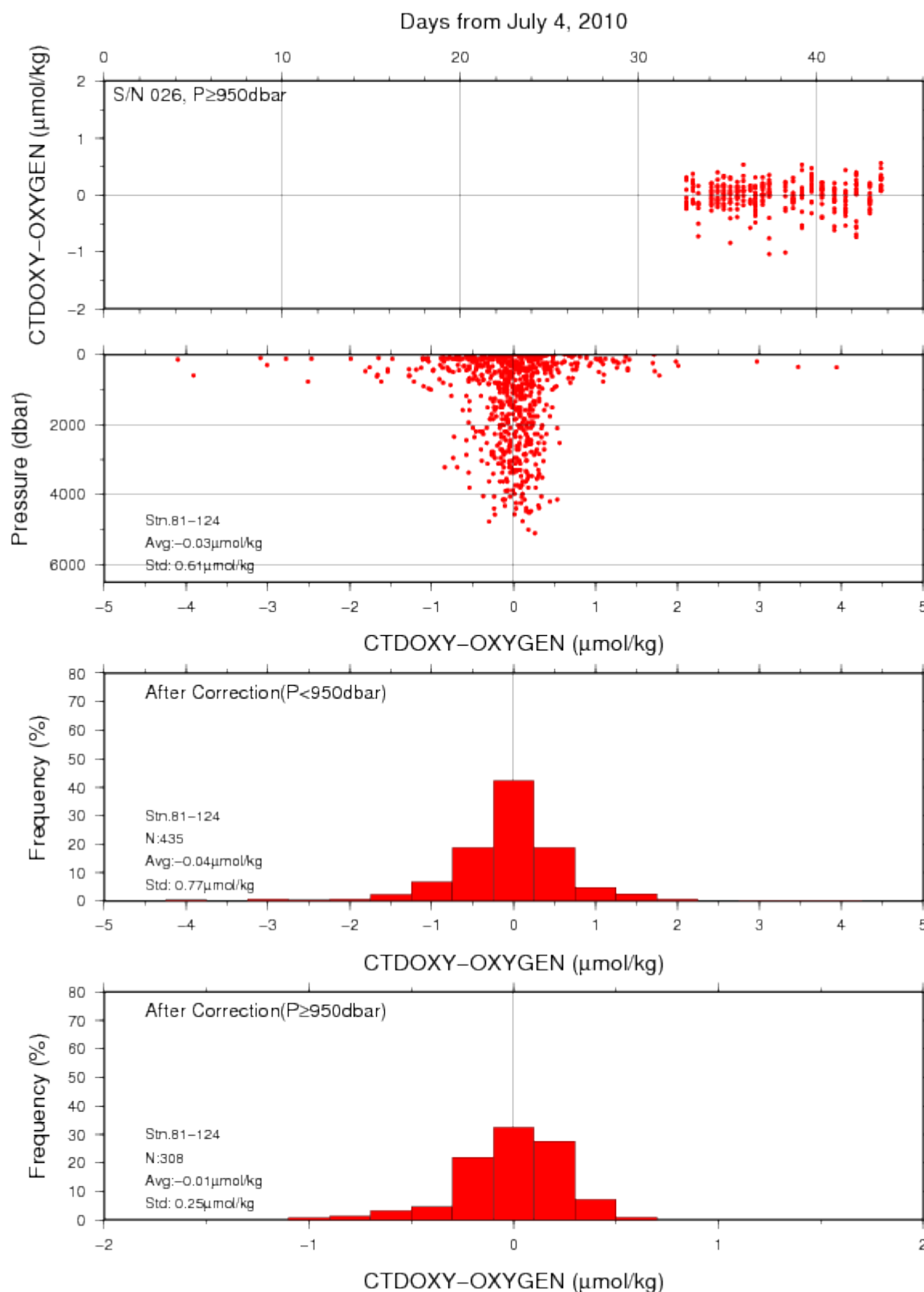


Figure C.1.9. Difference between the CTD oxygen and bottle dissolved oxygen in the latter part of Leg 2. Red dots in upper two panels indicate the result of calibration. Lower two panels show histogram of the difference between calibrated oxygen and bottle oxygen.

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2. Bottle Salinity

(1) Personnel

Keizo SHUTTA (GEMD/JMA)

Takahiro SEGAWA (GEMD/JMA)

Yasuaki BUNGI (GEMD/JMA)

Tetsuya NAKAMURA (GEMD/JMA)

Yoshikazu HIGASHI (GEMD/JMA)

Tomoyuki KITAMURA (GEMD/JMA)

(2) Station occupied

A total of 68 stations (Leg 1: 40, Leg 2: 28) were occupied for bottle salinity. Station location and sampling layers of bottle salinity are shown in Figure C.2.1.

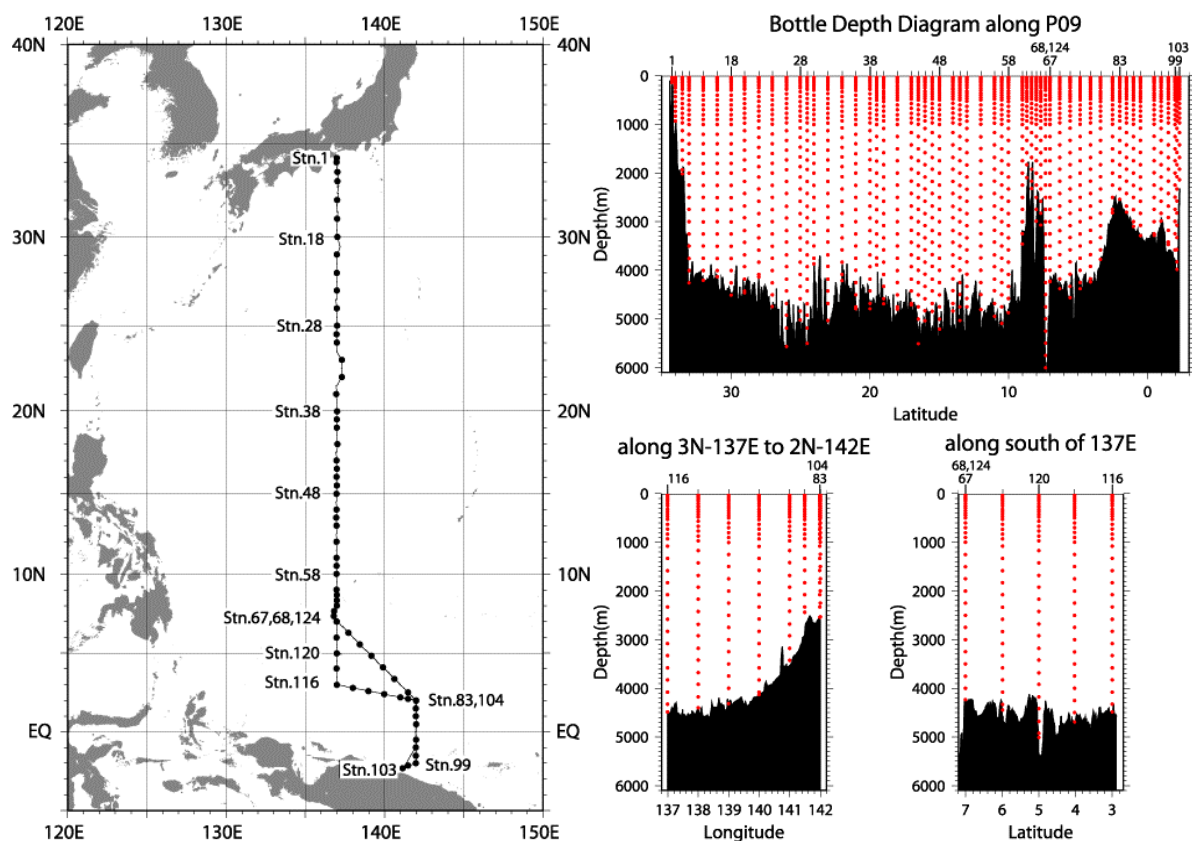


Figure C.2.1. Station location (left panel) and sampling layers of bottle salinity (right panel).

(3) Instruments and method

(3.1) Salinity sample collection

The bottles in which the salinity samples are collected and stored are 250 ml colorless transparent glass bottles with screw caps. Each bottle was rinsed three times with sample water and was filled to the shoulder of the bottle. The screw caps were also thoroughly rinsed. Salinity samples were wiped with dry clothes and stored for more than 24 hours in the same laboratory as the salinity measurement was made.

(3.2) Instruments and methods

The salinity analysis was carried out on AUTOSAL Laboratory Salinometer model 8400B (S/N69677; Guildline Instruments Ltd., Canada), which was modified by addition of an Ocean Science International peristaltic-type sample intake pump and two Guildline platinum thermometers model 9450. One thermometer monitored an ambient temperature and the other monitored a bath temperature. The resolution of the thermometers was 1 mK. The measurement system was almost same as *Aoyama et al* (2003). The salinometer was operated in a ship's laboratory air-conditioned at a bath temperature of 24 deg-C. Ambient temperature varied from approximately 21.5 to 23.5 deg-C, while bath temperature is very stable and varied within ± 0.001 deg-C. A measure of a double conductivity ratio of a sample is taken as a median of thirty-one readings. Data collection was started after 10 seconds and it took about 10 seconds to collect 31 readings by a personal computer. Data were sampled for the fourth and the fifth filling of the cell. In case the difference in the double conductivity ratio between this two fillings was smaller than 0.00003, the average value of the two double conductivity ratios was used to calculate the bottle salinity with the algorithm for the Practical Salinity Scale, 1978 (hereafter PSS-78; *UNESCO*, 1981). If the difference was greater than or equal to 0.00003, we measured the sixth filling of the cell. In case the double conductivity ratio of the sixth filling did not satisfy the criteria above, we measured the next filling of the cell and chose proper two fillings which satisfied the criteria. We continued these process at most ninth fillings.

(4) Result

Standardization control was set to 5.72 and all the measurements were done by this setting. During the whole measurement, readings of STANDBY were almost 6019 ± 0001 and those of ZERO were 0.00001 or 0.00002. We used IAPSO Standard Seawater batch P152 whose conductivity ratio was 0.99981 (double conductivity ratio is 1.99962) as the standard for salinity. We measured 2 or 3 bottles of P152 for each station, total amount was 187. If some readings of SSW bottle were extremely high or low, we measured another bottle of SSW.

Figure C.2.2 shows the history of ambient temperature, bath temperature, double conductivity ratio of standard sea water (P152) and time drift of P152 readings but for four bad bottles. In raw P152 readings, it was found offset and long-term variability. To remove long-term variability, raw P152 readings were corrected to label value 1.99962 in the least significant digit of readings. After the correction, SSW drift was steady within 1 digit of readings in each leg. The average of corrected SSW double conductivity ratio was 1.999621 and the standard deviation was 0.000010, which was equivalent to 0.0002 in salinity. The same correction was applied to sample readings. The correction of AUTOSAL drift for salinity measurements was from 0 to 2 digits of readings.

During measurement of a sample taken at Stn.28 (RF3676), one heater lamp of the salinometer was broken down so the result of measurement was omitted from salinity calibration.

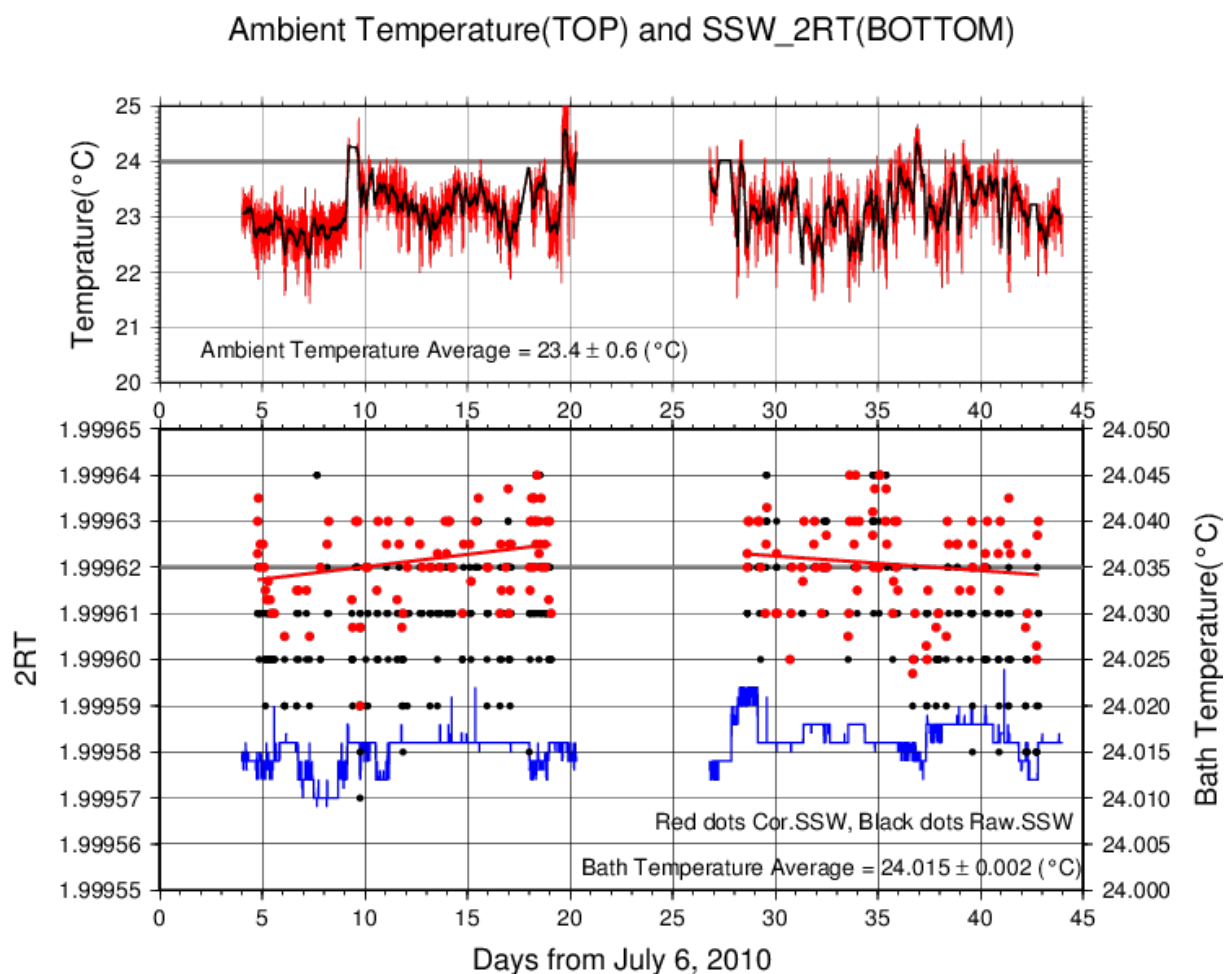


Figure C.2.2. The upper panel shows time-series of ambient temperature during cruise. The lower panel, black dots and red dots indicate raw and corrected time-series of the double conductivity ratio of the standard sea water (P152), red line indicate linear regression of corrected standard sea water for each leg, gray line indicate label value double conductivity ratio of P152 and blue line indicates time-series of bath temperature during cruise.

(5) Sub-Standard Water

We also used sub-standard seawater which was filtered by pore size of 10 micrometer and stored in a 20 liter cubitainer made of polyethylene and stirred for at least 24 hours before measuring. It was measured every six samples in order to check possible sudden drift of the salinometer. During the whole measurements, there was no detectable sudden drift of the salinometer except for measurement of a sample taken at Stn.28 (RF3676).

(6) Replicate and Duplicate Samples

We took 267 pairs of replicate samples and 210 pairs of duplicate samples during the cruise. [Figure C.2.3](#) and [Figure C.2.4](#) show the absolute difference among replicate and duplicate samples in salinity, respectively. There were 30 bad measurements and 2 questionable measurements in replicate pairs and 23 bad measurements, 4 questionable measurements and 1 failure of sampling in duplicate pairs. Excluding those bad and questionable measurements, the mean absolute difference and standard deviation in 237 pairs of replicate samples was 0.0004 ± 0.0004 in salinity and that in 182 pairs of duplicate samples was 0.0005 ± 0.0006 in salinity. Note that standard deviation was calculated by a procedure (SOP23) in *DOE* (1994).

Table C.2.1. Summary of assigned quality control flags

Flag	Definition	Salinity
2	Good	1716
3	Questionable	34
4	Bad (Faulty)	290
6	Replicate measurements	237
Total number of samples		2277

Autosal_Result of Replicate Sampling (N=237)

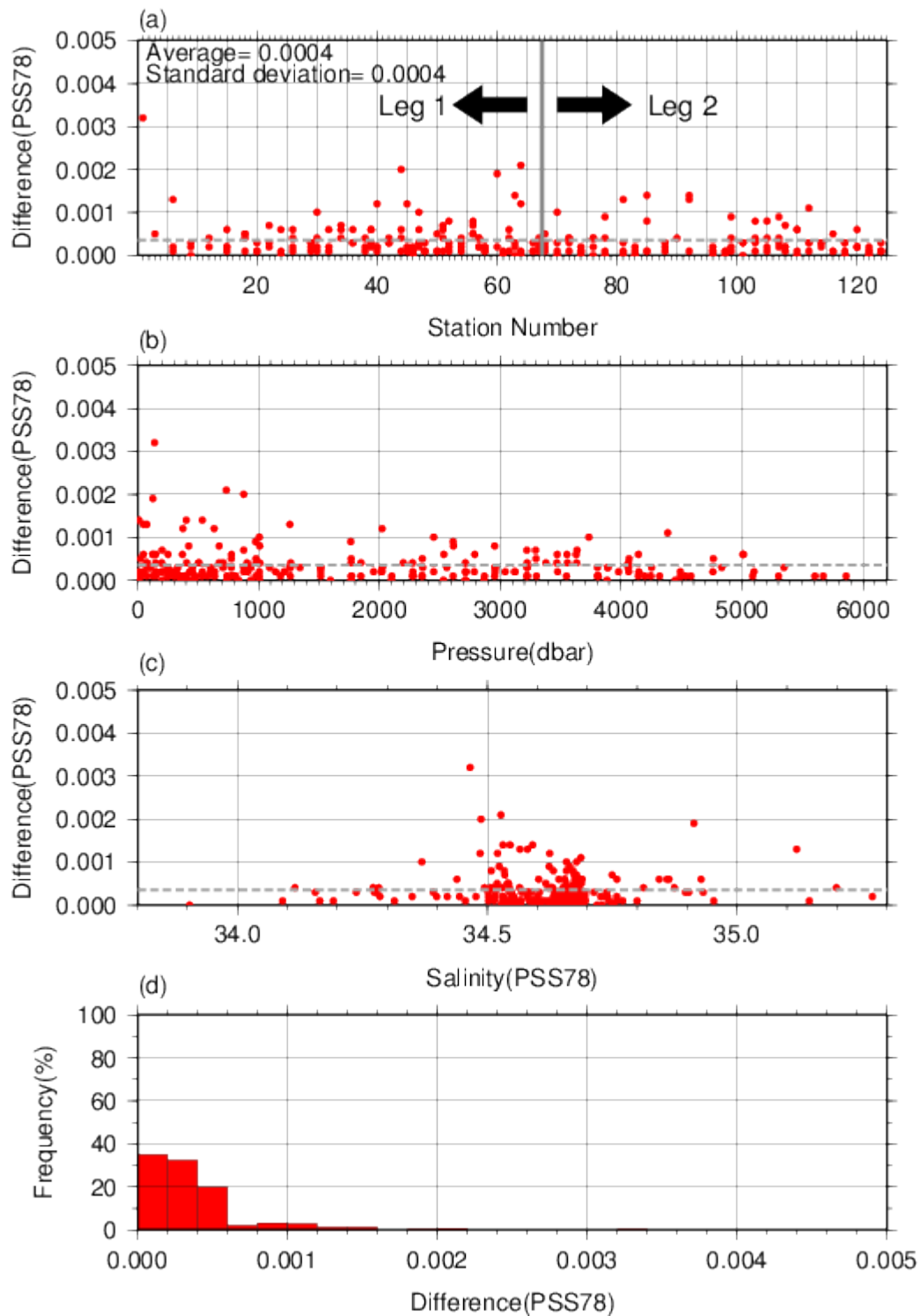


Figure C.2.3. Result of replicate samplings during this cruise against (a) station number, (b) sampling pressure and (c) salinity. Dotted line denotes the average of replicate samplings. Bottom panel (d) shows histogram of the result of replicate samplings.

Autosal_Result of Duplicate Sampling (N=182)

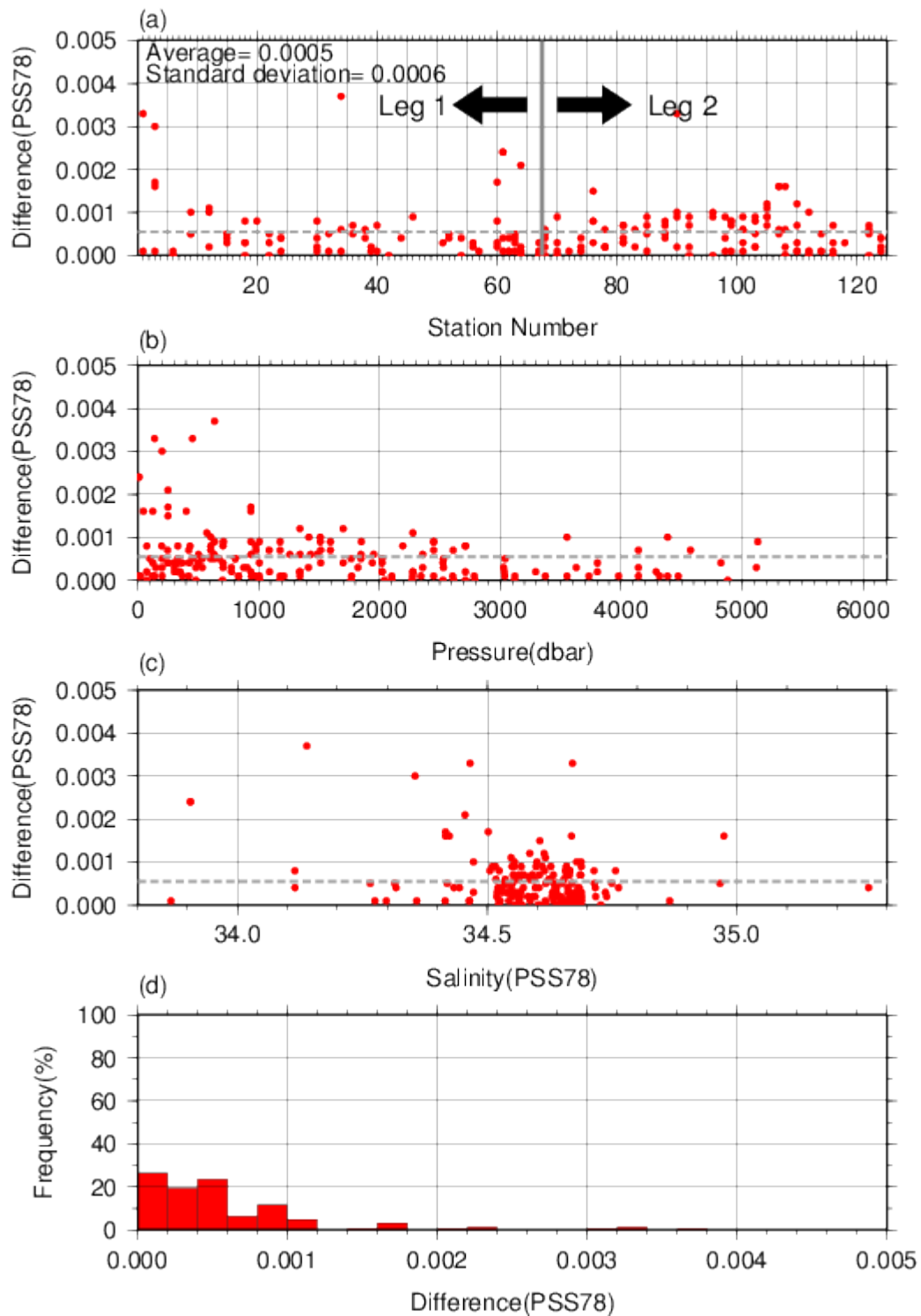


Figure C.2.4. Same as Fig.C.2.3 but for duplicate samplings.

References

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3. Bottle Oxygen

(1) Personnel

Yusuke TAKATANI (GEMD/JMA)

Shinichiro UMEDA (GEMD/JMA)

Sho HIBINO (GEMD/JMA)

(2) Station occupied

A total of 71 stations (Leg 1: 42, Leg 2: 29) were occupied for bottle oxygen. Station location and sampling layers of bottle oxygen are shown in Figure C.3.1.

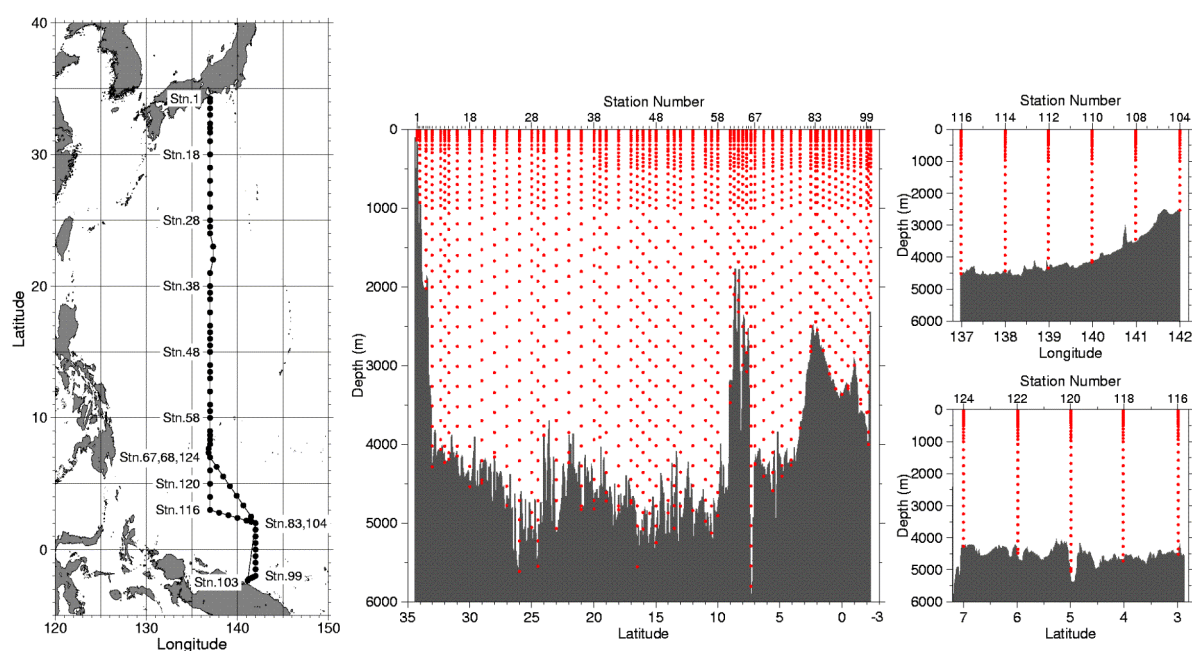


Figure C.3.1. Station location (left panel) and sampling layers of bottle oxygen (right panels).

(3) Reagents

• Manganous chloride solution (3 M) (Pickling Reagent-I)

Dissolved 600 g of $\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$ in deionized water, then dilute the solution with deionized water to a final volume of 1 L. $\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$ (Lot. CDP6460) used to make pickling reagent-I was guaranteed reagent manufactured by Wako Pure Chemical industries, Ltd.

• Sodium hydroxide (8 M) / sodium iodide solution (4 M) (Pickling Reagent-II)

Dissolved 320 g of NaOH in about 500 ml of deionized water, allow to cool, then add 600 g NaI and dilute with deionized water to a final volume of 1 L. NaOH (Lot. STN1103) and NaI (Lot. STQ5226) used to make pickling reagent-II were guaranteed reagent manufactured by Wako Pure Chemical industries, Ltd.

• Sulfuric acid solution (5 M)

Slowly add 280 ml concentrated H_2SO_4 to roughly 500 ml of deionized water. After cooling the final volume should be 1 L. H_2SO_4 (Lot. KWK1803) used to make sulfuric acid solution was guaranteed reagent manufactured by Wako Pure Chemical industries, Ltd.

• Sodium thiosulfate (0.04 M)

Dissolved 50 g of $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ and 0.4 g of Na_2CO_3 in deionized water, then dilute the solution with deionized water to a final volume of 5 L. $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ (Lot. PER3227) and Na_2CO_3 (Lot. WKF1312) used to make sodium thiosulfate were guaranteed reagent manufactured by Wako Pure Chemical industries, Ltd.

• Potassium iodate (0.001667 M)

Dry high purity KIO_3 for two hours in an oven at 130 deg-C. After weight out accurately KIO_3 , dissolve it in deionized water in a 5 L flask. Concentration of potassium iodate is determined by a gravimetric method. KIO_3 (Lot. 62404E) used to make potassium iodate was manufactured by MERCK & CO., Inc., and a purity of KIO_3 that is traceable to NIST (National Institute of Standards and Technology) standard reference material is $99.75 \pm 0.05 \%$.

(4) Instruments

Detector;

DOT-01X automatic photometric titrator manufactured by Kimoto Electronic Co. Ltd.

Burette for sodium thiosulfate;

APB-510 manufactured by Kyoto Electronic Co. Ltd./ 10 ml of titration vessel

Burette for potassium iodate;

Multipette stream 4986 and Combitip plus manufactured by eppendorf /10 ml of tip vessel

Bottle top dispenser for pickling reagent-I and II;

CalibrexTM 520 manufactured by SOCOREX ISBA S.A.

(5) Seawater sampling

Following procedure is based on a determination method in IOCCP Report No.14 (*Langdon*, 2010). Seawater samples were collected from 10-liters Niskin bottles attached the CTD-system and a stainless steel bucket for the surface. Seawater for bottle oxygen measurement was transferred from the Niskin sample bottle and a stainless steel bucket to a volumetrically calibrated dry glass bottles (ca. 120 ml, standard deviation of calibration = 0.008 ml). At least three times volume of the glass of sample water was overflowed. Two reagent solutions (Reagent-I and II) of 1 ml (standard deviation of calibration = 0.003 ml) each were added immediately, sample temperature was then measured by a thermometer. After the stopper was inserted carefully into the glass, the sample glass was shaken vigorously to mix the content and to disperse the precipitate finely. The precipitate has settled at least halfway down the glass, the glass was then shaken again vigorously to disperse the precipitate. The sample glasses containing pickled samples were stored in a laboratory until they were titrated. To prevent air from entering the flask, deionized water was added to the neck of the flask after sampling.

(6) Sample measurement

At least 30 minutes after the re-shaking, the pickled samples were measured on board. 1 ml sulfuric acid solution and a magnetic stirrer bar were added into the sample glass and stirring began. Samples were titrated by sodium thiosulfate solution whose molarity was determined by potassium iodate solution. Temperature of sodium thiosulfate during titration was recorded by a thermometer. The titrations were carried out using the titration apparatus, named DOT-01X. Dissolved oxygen concentration ($\mu\text{mol/kg}$) was calculated by the sample temperature at the fixation, CTD salinity, glass volume, and titrated volume of the sodium thiosulfate solution.

(7) Standardization

Concentration of sodium thiosulfate titrant (ca. 0.04 M) was determined by potassium iodate solution. Table C.3.1 shows a list of potassium iodate solution used in this cruise. Using a calibrated volumetric dispenser, 10 ml (standard deviation of calibration = 0.006 ml) of the standard potassium iodate solution was added to a glass with 100 ml of deionized water. Then, 1 ml of sulfuric acid solution, and 1 ml of pickling reagent solution-II and I were added into the glass in order. Amount of titrated volume of sodium thiosulfate (usually 5 times measurements average) gave the molarity of the sodium thiosulfate titrant. [Figure C.3.2](#) and [Table C.3.2](#) show the results of the standardization during this cruise. The sodium thiosulfate titrant of each batch was a mean of titrated volume of sodium thiosulfate on each day and a standard deviation of a concentration at 20 deg-C-of sodium thiosulfate on each day was an uncertainty caused by the standardization. A sodium thiosulfate of one batch was assumed to be one sodium thiosulfate titrant. The uncertainty of dissolved oxygen that caused by the standardization was estimated 0.01-0.13 %.

Table C.3.1. List of the standard potassium iodate solution in this cruise.

KIO ₃ batch	Conc. at 20°C (N)
KIO ₃ _I	0.009955±0.000003
KIO ₃ _IV	0.009967±0.000003

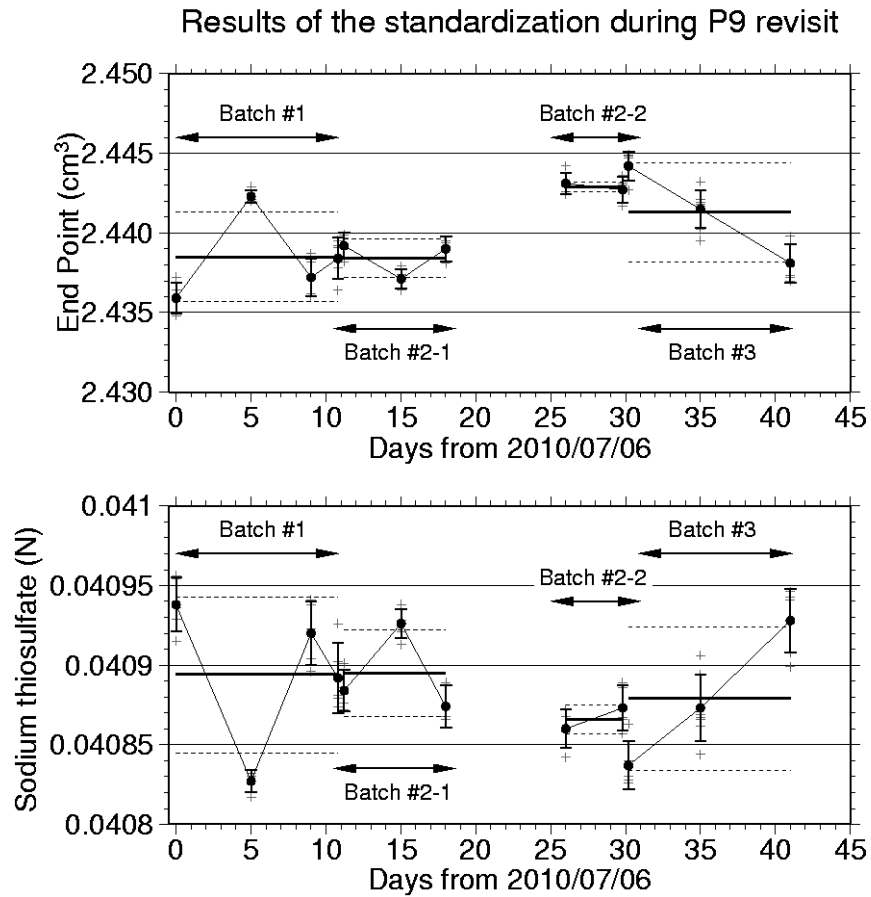


Figure C.3.2. Results of the standardization. Upper panel shows results of end point, bottom panel shows results of calculated concentration at 20 deg-C-of sodium thiosulfate. Crosses show each value for each standardization samples, and closed circles show the mean at each standardizations. Thick lines and dotted lines denote the means and 1 σ error for each batch of sodium thiosulfate, respectively.

Table C.3.2. Results of the standardization.

Leg	Date (UTC)	KIO ₃		Na ₂ S ₂ O ₃ (ml)		Stations
		Batch	Bottle	Batch	End Point	
1	2010/7/6	KIO ₃ _ IV	2	#1	2.4359	Stn.1
	2010/7/11	KIO ₃ _ IV	3	#1	2.4423	
	2010/7/15	KIO ₃ _ IV	4	#1	2.4372	Stn.43
	2010/7/17	KIO ₃ _ IV	5	#1	2.4384	
		Na ₂ S ₂ O ₃ #1			2.4385±0.0028	
	2010/7/17	KIO ₃ _ IV	5	#2	2.4392	Stn.44
	2010/7/21	KIO ₃ _ IV	6	#2	2.4371	
	2010/7/24	KIO ₃ _ IV	7	#2	2.4390	Stn.67
		Na ₂ S ₂ O ₃ #2 1			2.4384±0.0012	
	2010/8/1	KIO ₃ _ IV	9	#2	2.4431	Stn.68-
2	2010/8/5	KIO ₃ _ IV	10	#2	2.4427	Stn.84
		Na ₂ S ₂ O ₃ #2 2			2.4429±0.0003	
	2010/8/5	KIO ₃ _ IV	10	#3	2.4442	Stn.93
	2010/8/10	KIO ₃ _ IV	11	#3	2.4415	
	2010/8/16	KIO ₃ _ IV	12	#3	2.4381	Stn.105
		Na ₂ S ₂ O ₃ #4			2.4413±0.0031	

(8) Determination of the blank

The oxygen in the pickling reagents-I (1 ml) and II (1 ml) was assumed to be 7.6×10^{-8} mol (Murray *et al.*, 1968). The blank from the presence of redox species apart from oxygen in the reagents (the pickling reagents-I, II, and the sulfuric acid solution) was determined as follows. Using a calibrated volumetric dispenser, 1 ml of the standard potassium iodate solution was added to a glass with 100 ml of deionized water. Then, 1 ml of sulfuric acid solution, and 1 ml of pickling reagent solution-II and I were added into the glass in order. First, the sample was titrated to the end-point by sodium thiosulfate solution. Then, the sample was titrated again to the end-point after added a further 1 ml of the standard potassium iodate solution. The blank was determined by difference between the first (1 ml of KIO₃) titrated volume of the sodium thiosulfate and the second (2 ml of KIO₃) one. Because reagents set were prepared two sets (set A and B), the blank in each sets were determined. Usually, the results of 5 times blank determinations were averaged (Table C.3.3). The standard deviation of the blank determination during this cruise was 0.0010 (set A) and 0.0011 (set B) ml, c.a. 0.02 %.

Table C.3.3. Result of the blank determinations.

Date	Na ₂ S ₂ O ₃	Blank (ml)		Samples
(UTC)	Batch	Set A	Set B	(stations)
2010/7/6	#1	0.0008	0.0004	Stn.1-Stn.12
2010/7/9	#1	0.0014	0.0029	Stn.13-Stn.18
2010/7/11	#1	0.0024	0.0029	Stn.19-Stn.26
2010/7/13	#1	0.0018	0.0013	Stn.27-Stn.32
2010/7/15	#1	0.0021	0.0023	Stn.33-Stn.42
2010/7/17	#2	0.0015	0.0020	Stn.43-Stn.57
2010/7/21	#2	0.0015	0.0015	Stn.58-Stn.67
2010/8/1	#2	0.0042	0.0042	Stn.68-Stn.83
2010/8/5	#3	0.0028	0.0031	Stn.84-Stn.103
2010/8/10	#3	0.0027	0.0033	Stn.104-Stn.124

(9) Reagent blank

The blank determined in section (8), pure water blank ($V_{\text{blk, dw}}$) can be represented by equation (i),

$$V_{\text{blk, dw}} = V_{\text{blk, ep}} + V_{\text{blk, reg}} \quad (\text{i})$$

where

$V_{\text{blk, ep}}$ = blank due to differences between the measured end-point and the equivalence point;

$V_{\text{blk, reg}}$ = blank due to oxidants or reductants in the reagent.

Here, the reagent blank ($V_{\text{blk, reg}}$) was determined by following procedure. 1 ml of the standard potassium iodate solution and 100 ml of deionized water were added to two glasses each. 1 ml of sulfuric acid solution, pickling reagent solution-II and I each were added into the first glass in order. Then, two times volume of the reagents (2 ml of sulfuric acid solution, pickling reagent solution-II and I each) was added to the second glass. The reagent blank was determined by difference between the first (3 ml of the total reagent volume added) titrated volume of the sodium thiosulfate and the second (6 ml of the total reagent volume added) one. We also carried out experiments for three and four times volume of the reagents. The results are shown in [Figure C.3.3](#).

The relation between difference of the titrant ($\text{Na}_2\text{S}_2\text{O}_3$) volume and the volume of the reagents added (V_{reagent}) is expressed by equation (ii),

$$\text{Difference of the titrant volume} = -0.0023V_{\text{reagent}} \quad (\text{ii})$$

$V_{\text{blk, reg}}$ was estimated to be about -0.007 ml, suggesting that about $0.04 \mu\text{mol}$ of reductants was contained in every 3 ml of the reagents added.

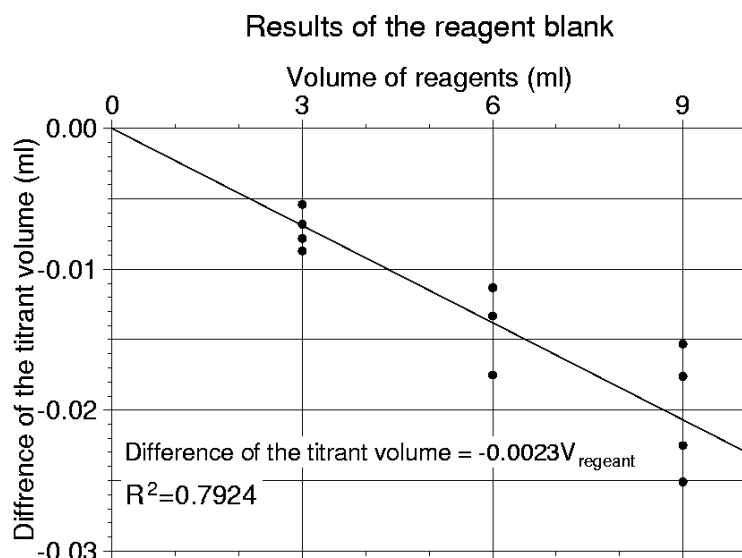


Figure C.3.3. Blank (ml) due to redox species apart from oxygen in the reagents.

(10) Sample blank

Blank due to redox species other than oxygen in the sample ($V_{\text{blk, spl}}$) can be a potential source of measurement error. The total blank during the seawater measurement, the seawater blank ($V_{\text{blk, sw}}$) can be represented by equation (iii).

$$V_{\text{blk, sw}} = V_{\text{blk, spl}} + V_{\text{blk, dw}} \quad (\text{iii})$$

If the pure water blank ($V_{\text{blk, dw}}$) that is determined in section (9) is identical both in pure water and in seawater, the difference between the seawater blank and the pure water one gives the sample blank ($V_{\text{blk, spl}}$).

Here, $V_{\text{blk, spl}}$ was determined by following procedure. Seawater sample was collected in the calibrated volumetric glass (c.a. 120 ml) without the pickling. Then 1 ml of the standard potassium iodate solution, sulfuric acid solution, and pickling reagent solution-II and I each

were added into the glass in order. Additionally, a glass contained 100 ml of deionized water and 1 ml of the standard potassium iodate solution, sulfuric acid solution, pickling reagent solution-II and I was prepared. The difference of the titrant volumes of the seawater glass and the deionized water one gave the sample blank ($V_{\text{blk, spl}}$).

We measured vertical profiles of the sample blank at 3 stations (Table C.3.4). The sample blank ranged from 0.17 to 1.96 $\mu\text{mol/kg}$ and its vertical and horizontal variations are large. This result does not agree to reported values ranged from 0.4 to 0.8 $\mu\text{mol/kg}$ (*Culberson et al.*, 1991). It does not have been known about the magnitude and variability of the seawater blank, so this result should be discussed carefully. Ignorant of the sample blank will cause systematic errors in the oxygen calculations, but these errors are expected to be the same to all investigators and not to affect the comparison of results from different investigators (*Culberson*, 1994).

Table C.3.4. Results of the sample blank determinations during this cruise.

Station: Stn.75 4.45°N/139.53°E		Station: Stn.111 2.50°N/139.50°E		Station: Stn.115 2.91°N/137.50°E	
Pres. (dbar)	Blank ($\mu\text{mol/kg}$)	Pres. (dbar)	Blank ($\mu\text{mol/kg}$)	Pres. (dbar)	Blank ($\mu\text{mol/kg}$)
10.3	0.17	10.3	0.35	25.3	0.91
50.6	1.03	103.5	0.73	100.8	0.63
101.7	0.54	201.2	1.04	302.0	0.95
251.5	–	381.9	0.69	503.2	1.09
634.7	0.61	483.8	1.76	1,008.8	0.97
838.0	0.90	675.1	1.96	1,514.0	0.75
1,596.4	0.56	978.3	0.97	2,020.6	1.29
2,611.7	0.82	1,940.0	1.39	3,038.5	1.44
3,631.6	0.71	2,955.6	1.11	4,060.8	1.29
4,142.7	0.84	4,382.1	–	4,574.2	0.90

(11) Replicate sample measurement

Replicate samples were carried out at every bottle oxygen observation stations. Total amount

of the replicate sample pairs in good measurement (flag=6) was 234, and total amount of the removed pair (flag=3 or 4) was 14. The average and the standard deviation of the replicate measurement during this cruise were 0.17 ± 0.17 $\mu\text{mol/kg}$. The standard deviation was calculated by a procedure (SOP23) in *DOE* (1994). The difference between the replicate sample pairs did not depend on sampling pressure, measurement date and concentration of sample (Figure C.3.4). The averages and the standard deviations during Leg 1 and Leg 2 were 0.17 ± 0.17 (n=127) and 0.18 ± 0.16 (n=107) $\mu\text{mol/kg}$, respectively.

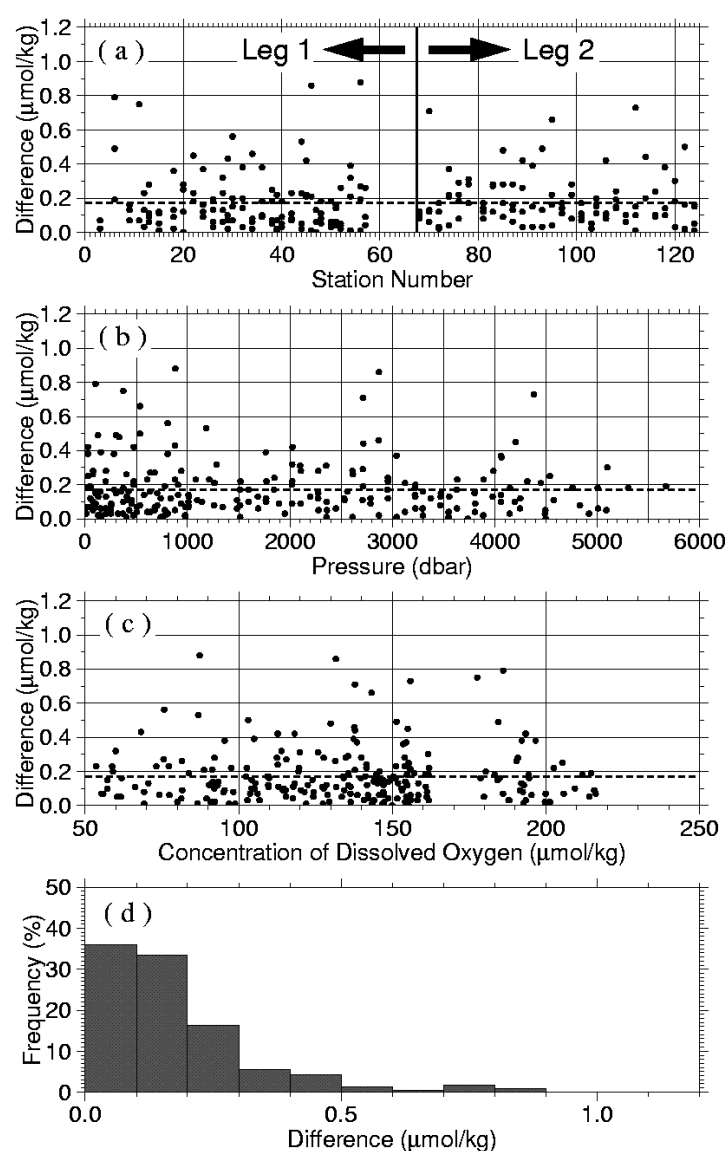


Figure C.3.4. Result of replicate samplings during this cruise against (a) station number, (b)

sampling pressure and (c) concentration of dissolved oxygen. Dotted line denotes the average of replicate samplings. Bottom panel (d) shows histogram of the result of replicate samplings.

(12) Duplicate sample measurement

Duplicate samples that were seawater samples from two Niskin sample bottles that were collected at same depth were carried out at almost every bottle oxygen observation stations also. Total amount of the duplicate sample pairs in good measurement (flag=2) was 156, and total amount of the removed pair (flag=3 or 4) was 16. The average and the standard deviation of the duplicate measurement during this cruise were 0.22 ± 0.21 $\mu\text{mol/kg}$. The difference between the duplicate sample pairs did not depended on measurement date and concentration of sample, but the results of the duplicate measurement on surface and subsurface (above 1000 dbar) were large ([Figure C.3.5](#)). We thought that this reason was because water mass on a surface and a subsurface was not similar compared with that of an intermediate and a deep layer. The averages and the standard deviations during Leg 1 and Leg 2 were 0.26 ± 0.24 (n=60) and 0.20 ± 0.18 (n=96) $\mu\text{mol/kg}$, respectively.

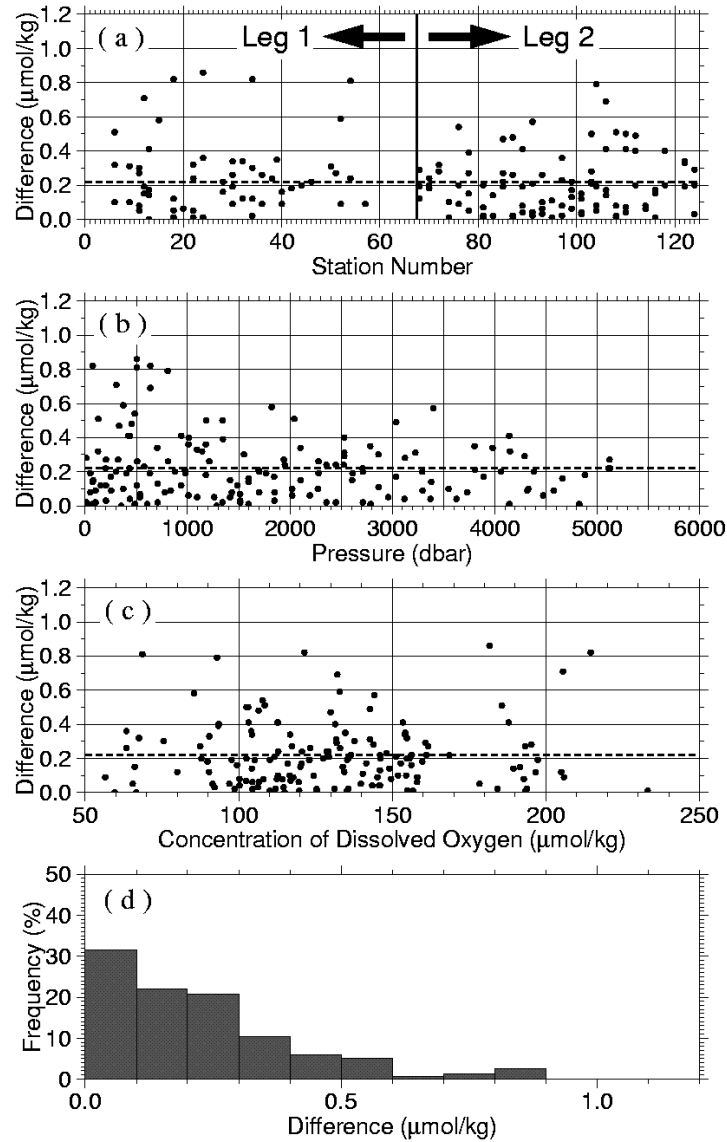


Figure C.3.5. Result of duplicate samplings during this cruise against (a) station number, (b) sampling pressure and (c) concentration of dissolved oxygen. Dotted line denotes the average of duplicate samplings. Bottom panel (d) shows histogram of the result of duplicate samplings.

(13) Mutual comparison between each standard potassium iodate

During the cruise, we performed the mutual comparison between two standard potassium iodate of difference Lot. in order to confirm the accuracy of our oxygen measurement and the bias of a standard potassium iodate. We measured concentration of a KIO_3 ($\text{KIO}_3\text{-I}$) against another KIO_3 ($\text{KIO}_3\text{-IV}$), and checked the difference between measurement value and theoretical one (Table C.3.5, Figure C.3.6). Error weighted means of measurement results of

KIO₃_I were 0.009947±0.000012 N. The averaged value of the KIO₃_I was so close to the theoretical value (0.009955±0.000003 N) that was prepared in laboratory. A good agreement among two standard potassium iodate confirmed that there was no systematic shift in our oxygen measurements during this cruise.

Table C.3.5. Results of mutual comparison of KIO₃_I against KIO₃_IV

Date (UTC)	KIO ₃ Batch	Measurement Value (N)
2010/7/6	KIO ₃ _I_4	0.009957±0.000013
2010/7/11	KIO ₃ _I_5	0.009940±0.000011
2010/7/15	KIO ₃ _I_6	0.009944±0.000011
2010/7/17	KIO ₃ _I_7	0.009943±0.000012
2010/7/17	KIO ₃ _I_7	0.009938±0.000012
2010/7/21	KIO ₃ _I_8	0.009951±0.000012
2010/7/24	KIO ₃ _I_9	0.009952±0.000013
2010/8/1	KIO ₃ _I_10	0.009956±0.000011
2010/8/5	KIO ₃ _I_11	0.009942±0.000011
2010/8/5	KIO ₃ _I_11	0.009941±0.000013
2010/8/10	KIO ₃ _I_12	0.009958±0.000012
2010/8/16	KIO ₃ _I_13	0.009946±0.000012
Weighted Mean		0.009947±0.000012

Results of Mutual Comparison during P9 revisit

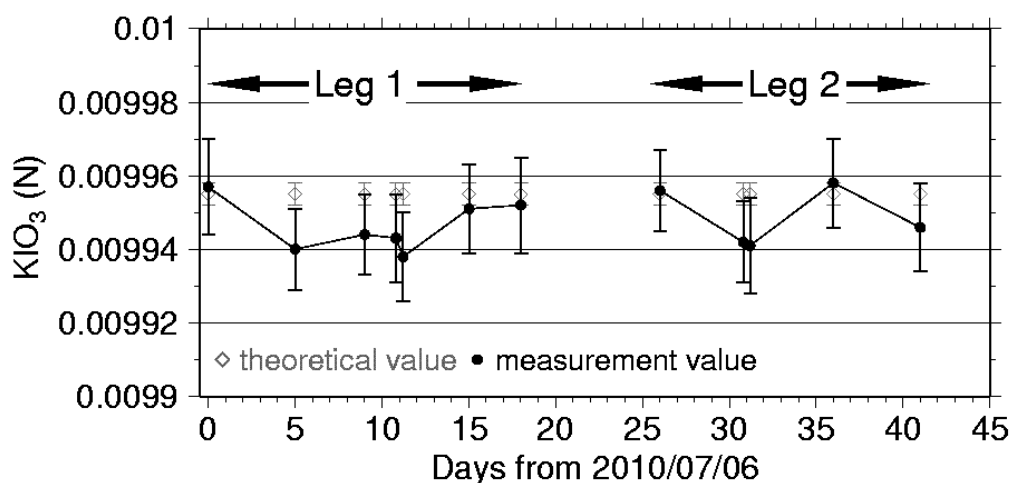


Figure C.3.6. Results of mutual comparison of KIO₃_I against KIO₃_IV. Closed circles show mean of measurement value with 1 σ error at each mutual comparison, and gray opened diamonds and error bar show the theoretical value and the uncertainty of the standard potassium iodate.

(14) Quality control flag assignment

Quality flag values were assigned to oxygen measurements using the code defined in IOCCP Report No.14 (Swift, 2010). Measurement flags of 2 (good), 3 (questionable), 4 (bad), 5 (not reported), and 6 (replicate measurement) have been assigned (Table C.3.6). The replicate data were averaged and flagged 6 if both of them were flagged 2. If either of them was flagged 3 or 4, a datum with “younger” flag was selected. For the choice between 2, 3, or 4, we basically followed a flagging procedure as listed below:

- Vertical sections against pressure and potential density were drawn. Any points not lying on a generally smooth curve were noted.
- Dissolved oxygen was then plotted against potential temperature, salinity and nutrients. If a datum deviated from a group of plots, it was flagged 3.
- If a datum was deviated from the mean $\pm 3\sigma$ on the section, datum flag was degraded from 2 to 3, or from 3 to 4.
- We Compared bottle oxygen with CTD oxygen at the sampling depth. If a datum deviated from CTD oxygen, datum flag was degraded from 2 to 3, or from 3 to 4.
- If the bottle flag was 4 (did not trip correctly), a datum was flagged 4 (bad). If the bottle flag was 3 (leaking) or 5 (unknown problem), a datum was flagged based on steps a, b, c, and d.

Table C.3.6. Summary of assigned quality control flags.

Flag	Definition	
2	Good	2353
3	Questionable	326
4	Bad (Faulty)	52
5	Not reported	1

6	Replicate measurements	234*
Total number of samples		2732*

*Samples of flag 6 are counted as flag 2

(15) Problems

A leak of sodium thiosulfate from a joint of burette was revealed at the standardization after Stn.67. From the comparison between bottle oxygen and the oxygen sensor (RINKO III manufactured by JFE Advantech Co. Ltd.), it was thought that this problem had happened from Stn.58 (Figure C.3.7). The data between Stn.58 and Stn.67 were flagged 3 or 4.

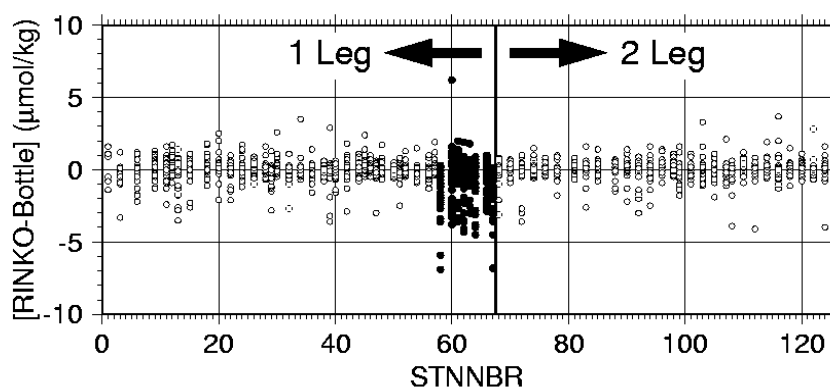


Figure C.3.7. Comparison between bottle oxygen and RINKO III. Closed circles show data between Stn.58 and Stn.67.

(16) Uncertainty in Oxygen data of this cruise

The reproducibility in this cruise determined by replicate samples and duplicate samples in section (11) and (12) was 0.17 ± 0.17 $\mu\text{mol/kg}$ and 0.22 ± 0.21 $\mu\text{mol/kg}$. Bottle oxygen data in this cruise were calculated based on IOCCP Report No.14 (Langdon, 2010). In these results, various uncertainties were included (ex. standardization, calibration of glass bottles, precision of burette etc.). Considering these uncertainty that can be estimated theoretically, it was estimated that the standard uncertainty of bottle oxygen data in this cruise is about 0.43 $\mu\text{mol/kg}$. However, it is impossible to estimate an accurate uncertainty because there is no reference material.

(17) Results

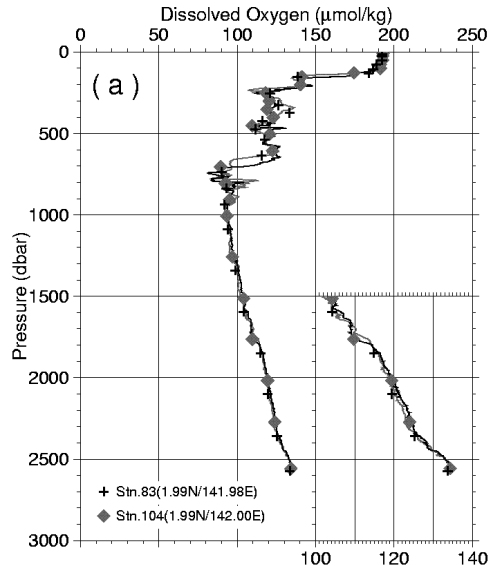
(17.1) Comparison at cross-stations during this cruise

Cross-stations during this cruise were two stations. The one was located at 2°N/142°E, the another was located 7°N/137°E.

At stations of Stn.83 (RF3731) and Stn.104 (RF3755), hydrocast sampling for dissolved oxygen was conducted two times at interval of about five days. Dissolved oxygen profiles of the two hydrocasts agreed well (Figure C.3.8). We compared interpolated data, because the sampling layers of the two hydrocasts were difference. In the layers deeper than 2000 dbar, difference of interpolated data between the two hydrocasts was calculated to be about $1.25 \pm 0.28 \text{ } \mu\text{mol/kg}$. In these layers, difference of the oxygen sensor between the two hydrocasts was also about $0.8 \pm 0.6 \text{ } \mu\text{mol/kg}$.

At stations of Stn.67 (RF3715), Stn.68 (RF3716), and Stn.124 (RF3772), hydrocast sampling for dissolved oxygen was conducted three times. Interval between the first and the second was about a week, interval between the second and the third was about two weeks. Dissolved oxygen profiles between the second and third hydrocasts agreed well, but the data of the first hydrocast had slightly larger than that of second and third hydrocast because of a leak of sodium thiosulfate from a joint of the burette (Figure C.3.7). In the layers deeper than 2000 dbar, difference between the second and third hydrocast was calculated to be about $0.08 \pm 0.64 \text{ } \mu\text{mol/kg}$.

Comparison at cross-stations(2°N,142°E) during P9 revisit



Comparison at cross-stations(7°N,137°E) during P9 revisit

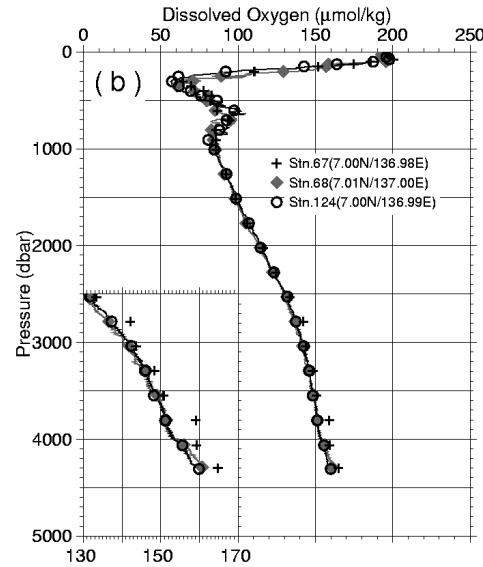


Figure C.3.8. Comparison of dissolved oxygen profiles between the first hydrocast (pluses), the second one (gray diamonds) and the third one (circles) at the cross-stations of (a) 2°N/142°E and (b) 7°N/137°E. Lines denote the profiles of the oxygen sensor.

(17.2) Comparison at cross-stations of WHP-P2 section in 1994 and 2004

We compared our oxygen data and one of WHP-P2 at a cross point, around 30°N/137°E. WHP-P2 line was observed two times, first in 1994 by *R/V Shoyo* belonged to Maritime Safety Agency of Japan (MSA) (present Japan Coast Guard (JCG)) and repeated in 2004 by *R/V Melville* belonged to Scripps Institution of Oceanography (SIO). Dissolved oxygen profiles between one in this cruise and in 2004 agreed well (Figure C.3.9), and the difference below 2000 dbar is $0.18 \pm 0.75 \mu\text{mol/kg}$. But it was found that oxygen data in this cruise were significantly lower than those in 1994 in deep layers, the differences below 2000 dbar is $-4.14 \pm 2.45 \mu\text{mol/kg}$. This difference should be discussed carefully.

(17.3) Comparison at cross-stations of WHP-P3 section in 1985 and 2005/06

We compared our oxygen data and one of WHP-P3 at a cross point, around 24°N/137°E. WHP-P3 line was observed two times, first in 1985 by *R/V Thomas G. Thompson* belonged to SIO and repeated in 2005/06 by *R/V Mirai* belong to Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Dissolved oxygen profiles between one in this cruise and in

2005/06 agreed well (Figure C.3.9). The differences between oxygen data below 2000 dbar in this cruise and these in 1985, or in 2005/06 are -1.76 ± 0.53 , -0.17 ± 1.01 $\mu\text{mol/kg}$, respectively. For the comparison with oxygen data in 1985, the offset value is larger than reported adjustments, about minus 0.3 $\mu\text{mol/kg}$ (Johnson *et al.*, 2001; Gouretski and Jancke, 2001). For the comparison with oxygen data in 2005/06, it should also be noted that the relatively large difference in deep layer ranged from about 1000 to 2000 dbar. Though it might be caused by the slight difference of the observation position, it is necessary to discussed it carefully.

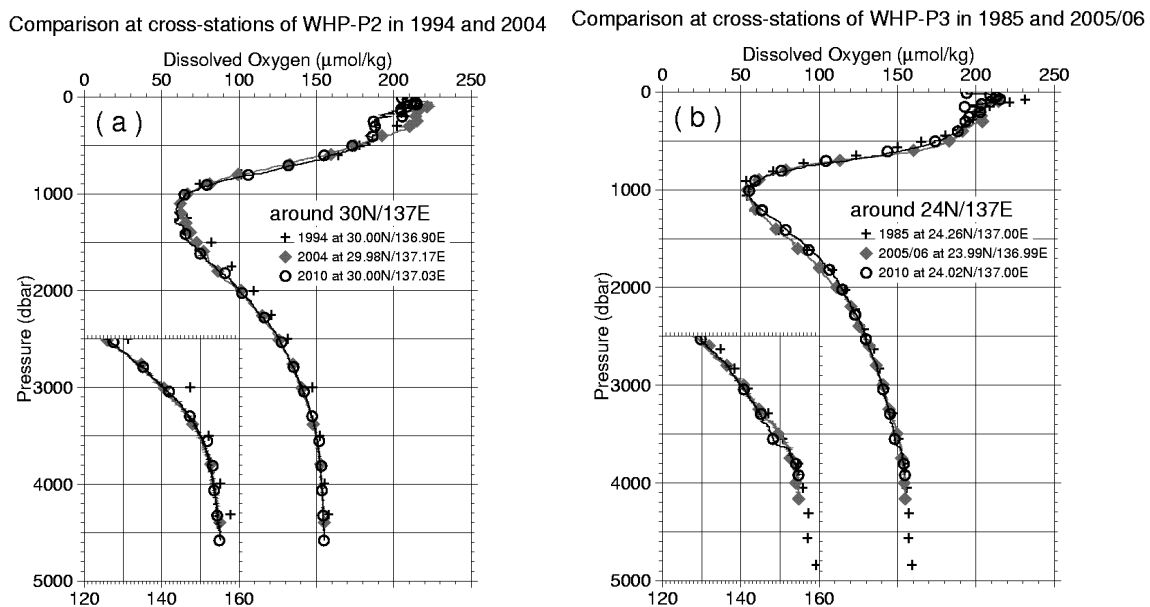


Figure C.3.9. Comparison of dissolved oxygen profiles at cross-stations of (a) WHP-P2 and (b) WHP-P3. Pluses, gray diamonds and opened circles show the first observation, the second one and this cruise, respectively. Lines denote the profiles of the oxygen sensor.

(17.4) Comparison with WHP-P9 oxygen data in 1994

We compared oxygen data in this cruise and one of WHP-P9 in 1994. In deep layers in a wide region, dissolved oxygen have been decreased from 1994 (Figure C.3.10). Below 2000 m, the difference in average is calculated in -1.47 ± 2.48 $\mu\text{mol/kg}$ (Figure C.3.11). This offset value is closed to reported adjustments, about -1 $\mu\text{mol/kg}$ for dissolved oxygen data of WHP-P9 (Johnson *et al.*, 2001; Gouretski and Jancke, 2001). Therefore, it was thought that oxygen

measurements in this cruise were conducted correctly.

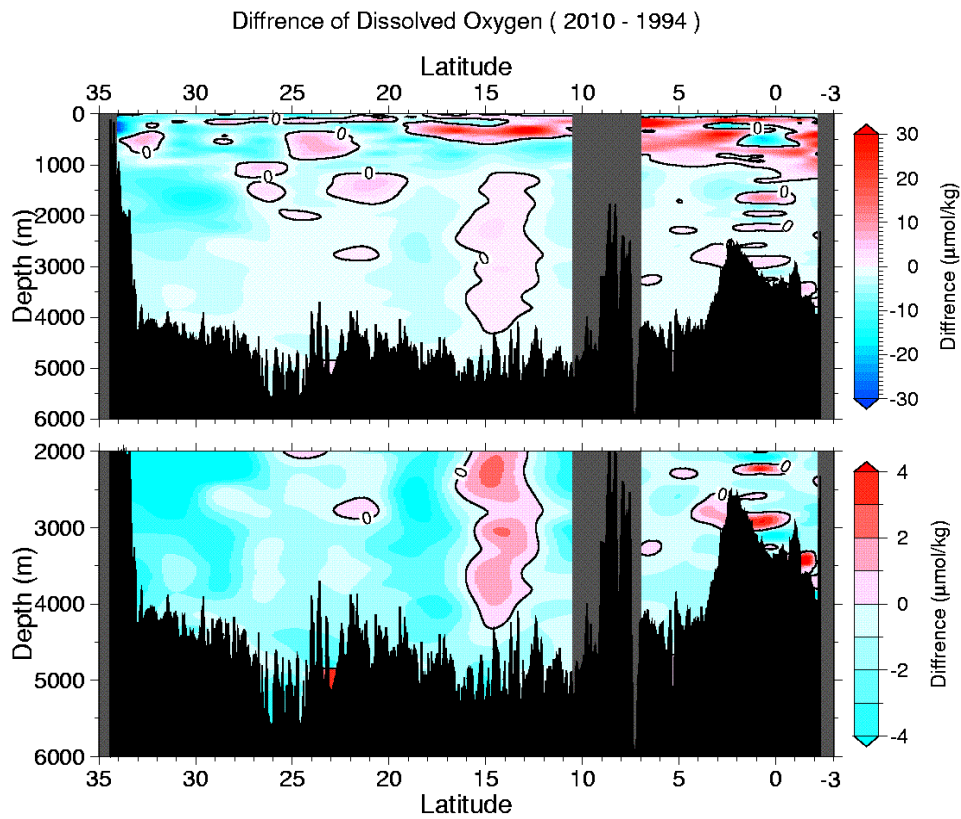


Figure C.3.10. Difference of dissolved oxygen between 2010 and 1994 against water depth.

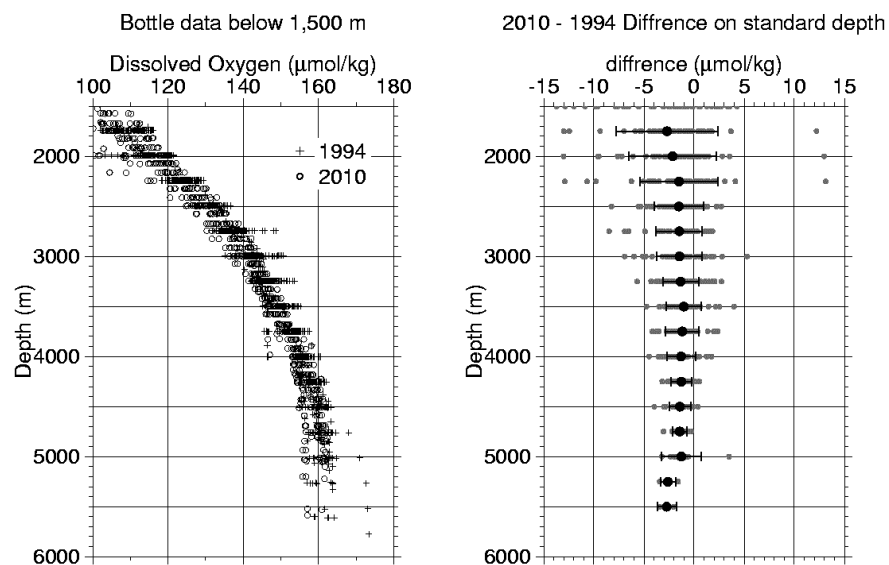


Figure C.3.11. Bottle oxygen data in 1994 (pluses) and 2010 (circles) below 1500 m (left panel) and difference of dissolved oxygen on the standard depth (right panel). Black closed circles denote mean of the differences with 1 σ error.

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4. Nutrients

(1) Personnel

Kazuhiro SAITO (GEMD/JMA)

Hiroyuki FUJIWARA (GEMD/JMA)

Takahiro KITAGAWA (GEMD/JMA)

(2) Station occupied

A total of 104 stations (Leg1: 61, Leg2: 43) were occupied for nutrients. Station location and sampling layers of nutrients are shown in Figure C.4.1.

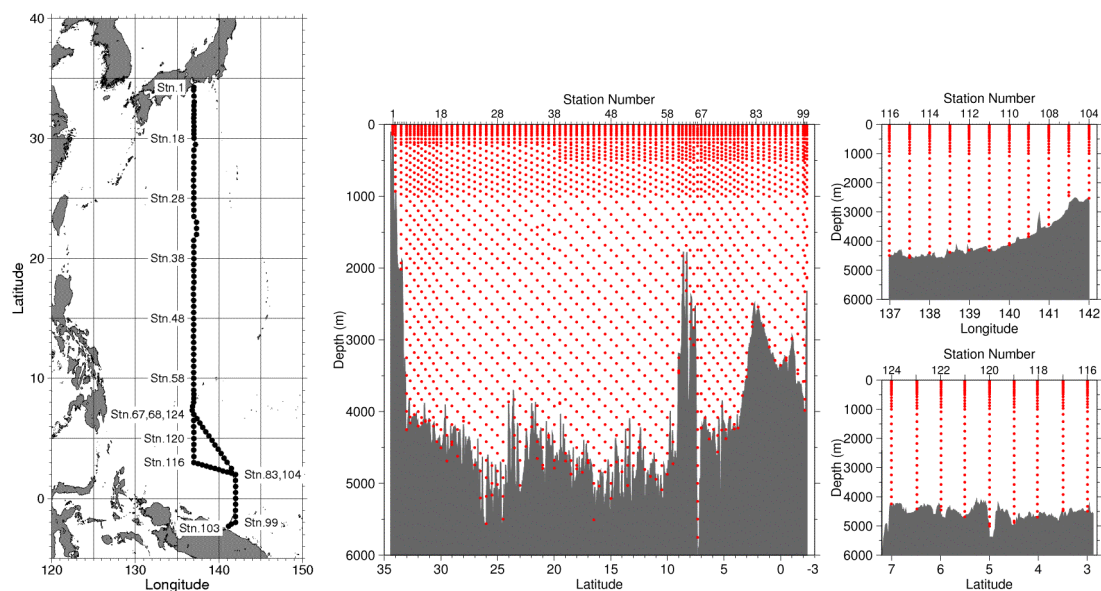


Figure C.4.1. Station location (left) and sampling layers (right) of nutrients.

(3) Instrument and Method

(3.1) Analytical detail using Auto Analyzer III systems (BLTEC)

The nutrients analyses were carried out on 4-channel Auto Analyzer III (BLTEC). Measured Parameters are nitrate + nitrite, nitrite, phosphate and silicate.

Nitrate + nitrite and nitrite are analyzed according to the modification method of *Armstrong* (1967). The sample nitrate is reduced to nitrite in a cadmium tube inside of which is coated with metallic copper. The sample stream with its equivalent nitrite is treated with an acidic,

sulfanilamide reagent and the nitrite forms nitrous acid which reacts with the sulfanilamide to produce a diazonium ion. N-1-Naphthylethylene-diamine added to the sample stream then couples with the diazonium ion to produce a red, azo dye. With reduction of the nitrate to nitrite, both nitrate and nitrite react and are measured; without reduction, only nitrite reacts. Thus, for the nitrite analysis, no reduction is performed and the alkaline buffer is not necessary.

The phosphate analysis is a modification of the procedure of *Murphy and Riley* (1962). Molybdic acid is added to the seawater sample to form phosphomolybdic acid which is in turn reduced to phosphomolybdous acid using L-ascorbic acid as the reductant.

The silicate method is analogous to that described for phosphate. The method used is essentially that of *Grasshoff et al.* (1983), wherein silicomolybdic acid is first formed from the silicate in the sample and added molybdic acid, then the silicomolybdic acid is reduced to silicomolybdous acid, or "molybdenum blue," using L-ascorbic acid as the reductant.

The flow diagrams and reagents for each parameter are shown in [Figures C.4.2-C.4.5](#).

(3.2) Nitrate Reagents

Ammonium chloride (buffer), 0.7 M (0.04 % w/v);

Dissolve 190 g Ammonium chloride, NH_4Cl , in ca. 5000 ml of milli-Q water, add about 5 ml Ammonia (aq.), adjust pH 8.2-8.5.

Sulfanilamide, 0.06 M (1 % w/v);

Dissolve 5 g Sulfanilamide, $4\text{-NH}_2\text{C}_6\text{H}_4\text{SO}_3\text{H}$, in 430 ml milli-Q water, add 70 ml concentrated HCl. After mixing, 1 ml Brij-35 (22 % w/w) is added.

N-1-Naphtylethylene-diamine dihydrochloride (NEDA), 0.004 M (0.1 % w/v);

Dissolve 0.5 g NEDA, $\text{C}_{10}\text{H}_7\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2\cdot 2\text{HCl}$, in 500 ml milli-Q water.

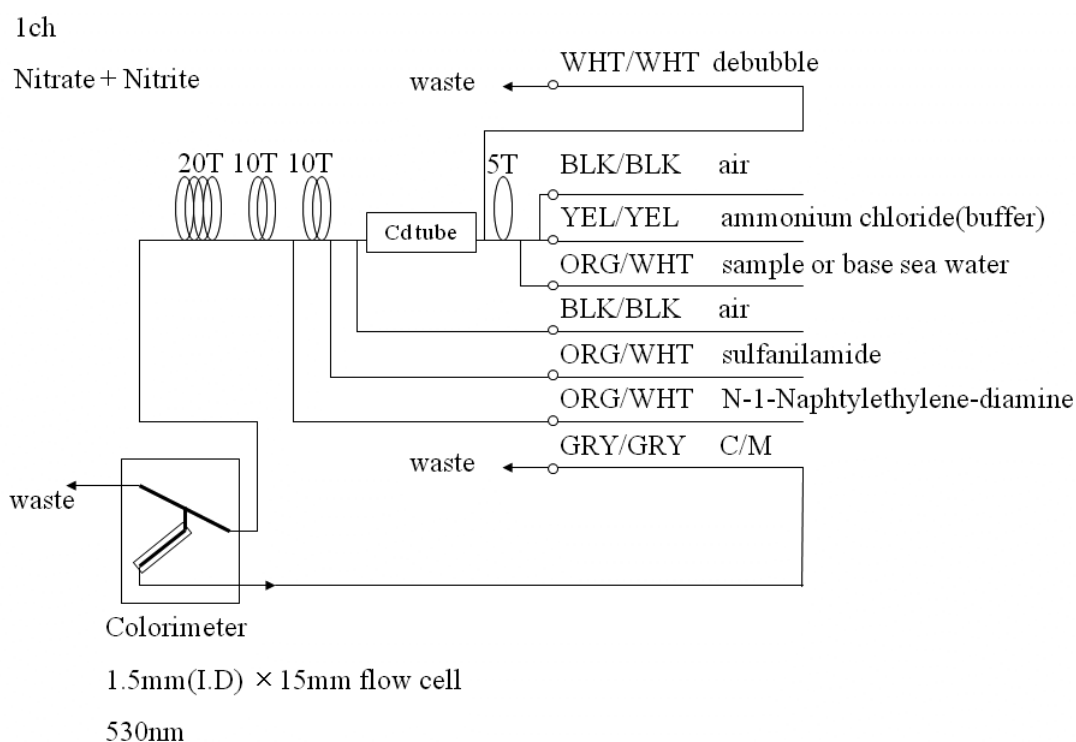


Figure C.4.2. 1ch. (Nitrate + Nitrite) Flow diagram.

(3.3) Nitrite Reagents

Sulfanilamide, 0.06 M (1 % w/v);

Dissolve 5 g Sulfanilamide, 4-NH₂C₆H₄SO₃H, in 430 ml milli-Q water, add 70 ml concentrated HCl. After mixing, 1 ml Brij-35 (22 % w/w) is added.

N-1-Naphtylethylene-diamine dihydrochloride (NEDA), 0.004 M (0.1 % w/v);

Dissolve 0.5 g NEDA, C₁₀H₇NH₂CH₂CH₂NH₂·2HCl, in 500 ml milli-Q water.

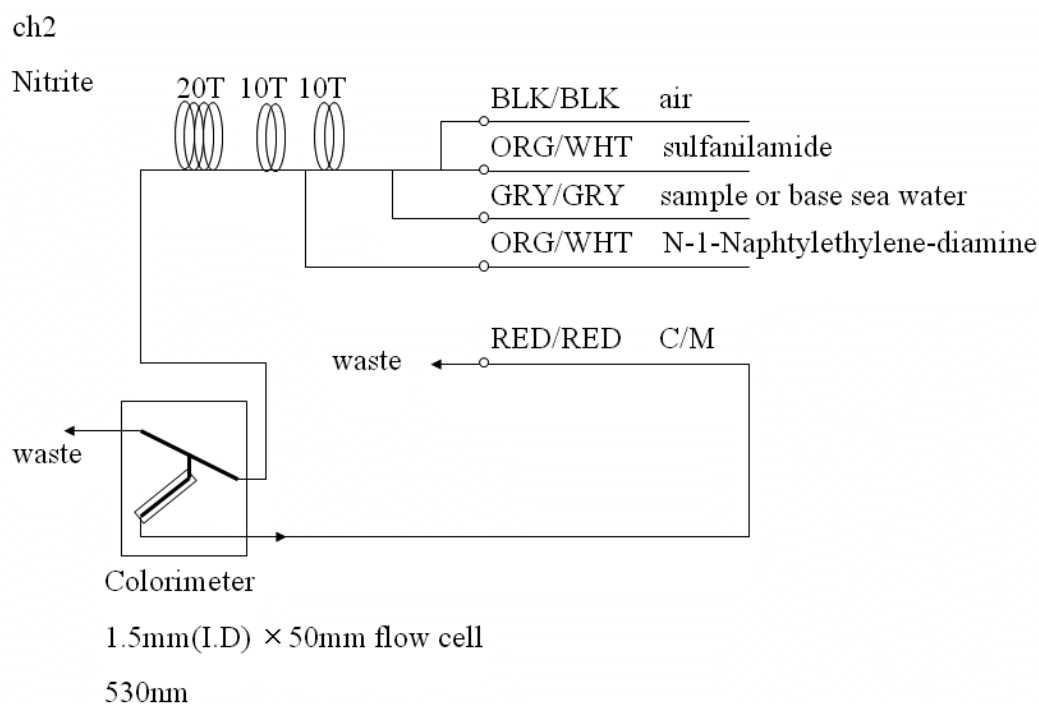


Figure C.4.3. 2ch. Nitrite Flow diagram.

(3.4) Phosphate Reagents

Ammonium molybdate, 0.005 M (0.6 % w/v);

Dissolve 3 g Ammonium molybdate(VI) tetrahydrate, $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$, and 0.05 g Potassium antimonyl tartrate, $\text{C}_8\text{H}_4\text{K}_2\text{O}_{12}\text{Sb}_2 \cdot 3\text{H}_2\text{O}$, in 400 ml milli-Q water and add 100 ml H_2SO_4 (12.6N). After mixing, 2 ml Sodium dodecyl sulfate (15 % solution in water) is added.

L(+)-Ascorbic acid, 0.08 M (1.5 % w/v);

Dissolve 4.5 g L(+)-Ascorbic acid, $\text{C}_6\text{H}_8\text{O}_6$, in 300 ml milli-Q water. After mixing, 10 ml Acetone is added. Freshly prepared before every measurement.

ch3

Phosphate

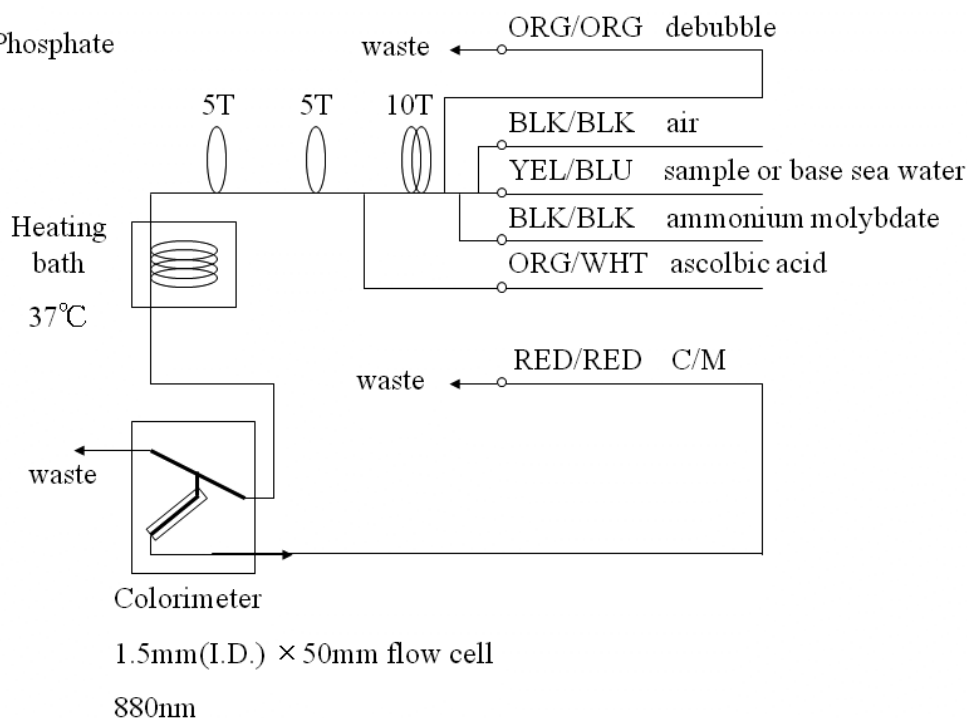


Figure C.4.4. 3ch. Phosphate Flow diagram.

(3.5) Silicate Reagents

Ammonium molybdate, 0.005 M (0.6 % w/v);

Dissolve 3 g Ammonium molybdate (VI) tetrahydrate, $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$, in 495 ml milli-Q water and added 5 ml H_2SO_4 (12.6N). After mixing, 2 ml Sodium dodecyl sulfate (15 % solution in water) is added.

Oxalic acid, 0.4 M (5 % w/v);

Dissolve 25 g Oxalic acid dihydrate, $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$, in 500 ml milli-Q water.

L(+)-Ascorbic acid, 0.08 M (1.5 % w/v);

Dissolve 4.5 g L(+)-Ascorbic acid, $\text{C}_6\text{H}_8\text{O}_6$, in 300 ml milli-Q water. After mixing, 10 ml Acetone is added. Freshly prepared before every measurement.

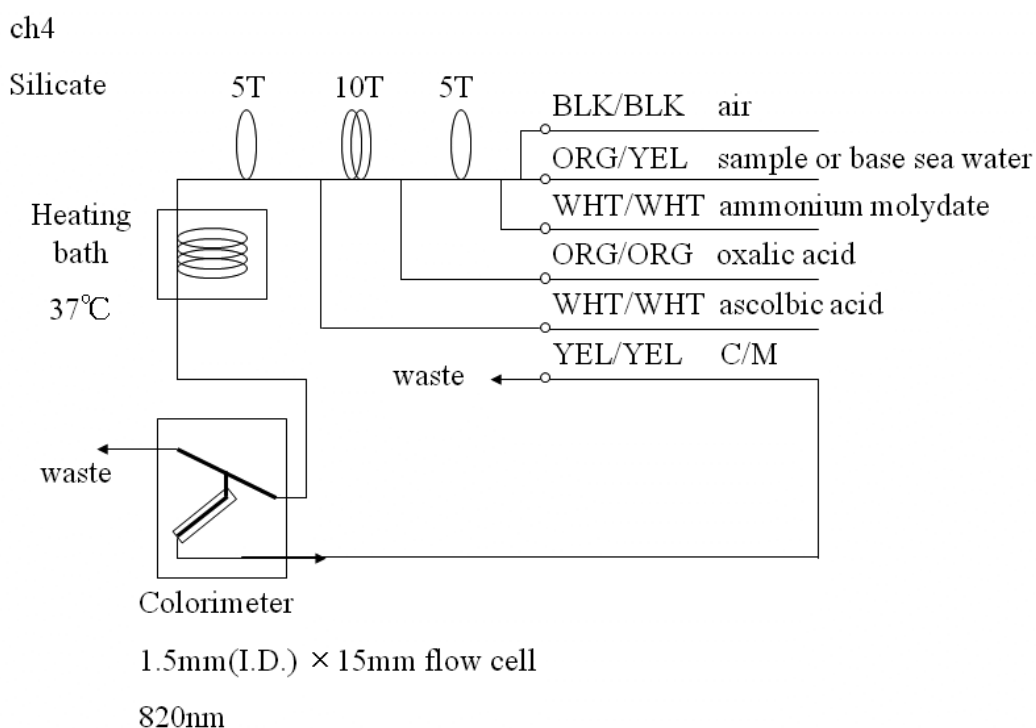


Figure C.4.5. 4ch. Silicate Flow diagram.

(3.6) Sampling procedures

Seawater samples were collected from 10-liters Niskin bottle attached CTD-system and a stainless steel bucket for the surface. Sampling of nutrients followed that oxygen and trace gases. Samples were drawn into 10 ml polymethylpenten vials with sample drawing tubes. These were rinsed three times before filling and vials were capped immediately after the drawing.

No transfer was made and the vials were set an auto sampler tray directly. Samples were analyzed immediately after collection.

(3.7) Data processing

Raw data from Auto Analyzer III were recorded at 1-second interval and were treated as follows;

- Calculate 11-second moving average.

- Check the shape of each peak and position of peak values taken, and then change the positions of peak values taken if necessary.
- Baseline correction was done basically using liner regression.
- Reagent blank correction was done basically using liner regression.
- Carry-over correction was applied to peak heights of each sample.
- Sensitivity correction was applied to peak heights of each sample.
- Refraction error correction was applied to peak heights of each seawater sample.
- Calibration curves to get nutrients concentration were assumed quadratic expression.
- Load pressure and salinity from CTD data to calculate density of seawater.
- Convert data from $\mu\text{mol/l}$ to $\mu\text{mol/kg}$.

(4) Nutrients standards

(4.1) Volumetric Laboratory Ware of in-house standards

All volumetric ware used were gravimetrically calibrated. Polymethylpenten volumetric flasks were gravimetrically calibrated at the temperature of use within 3 - 4 K.

Volumetric flasks

The weights obtained in the calibration weightings were corrected for the density of water and air buoyancy.

Pipettes and pipettors

All pipettes have nominal calibration tolerances of 0.1 % or better. These were gravimetrically calibrated in order to verify and improve upon this nominal tolerance.

(4.2) Reagents, general considerations

Specifications

For nitrate standard, “potassium nitrate 99.995 suprapur” provided by Merck, CAS No. : 7757-79-1, was used.

For phosphate standard, “potassium dihydrogen phosphate anhydrous 99.995 suprapur” provided by Merck, CAS No. : 7778-77-0, was used.

For nitrite standard, “sodium nitrite GR for analysis ACS, Reag. Ph Eur” provided by Merck, CAS No. : 7632-00-0, was used.

For the silicate standard, we use “Silicon standard solution traceable to SRM from NIST SiO₂ in NaOH 0.5 mol/l 1000 mg/l Si CertiPUR” provided by Merck, which lot number is HC814662 is used. The silicate concentration is certified by NIST-SRM3150 with the uncertainty of 0.5 %.

Ultra pure water

Ultra pure water (Milli-Q water) freshly drawn was used for preparation of reagents, higher concentration standards and for measurement of reagent and system blanks.

Low Nutrient Seawater (LNSW)

Surface water having low nutrient concentration was taken and filtered using 10 µm pore size membrane filter. This water is stored in 20 liter flexible container with paper box.

(4.3) Concentrations of nutrients for A, B and C standards

Concentrations of nutrients for A, B and C standards are set as shown in Table C.4.1. The C standard is prepared according recipes as shown in [Table C.4.2](#). All volumetric laboratory tools were calibrated prior the cruise as stated in subsection (4.1). Then the actual concentration of nutrients in each fresh standard was calculated based on the ambient, solution temperature and determined factors of volumetric lab. wares. The calibration curves for each run were obtained using 4 levels, C-1, C-2, C-3 and C-4.

Table C.4.1. Nominal concentrations of nutrients for A, B and C standards.

	Unit: µmol/l					
	A	B	C-1	C-2	C-3	C-4 (Full scale)
NO ₃	26200	520	LNSW*	1/3 Full scale	2/3 Full scale	43.4
NO ₂	12500	250	LNSW*	1/3 Full scale	2/3 Full scale	2.0
PO ₄	2040	40.5	LNSW*	1/3 Full scale	2/3 Full scale	3.2
Si	35600	1950	LNSW*	1/3 Full scale	2/3 Full scale	155

Table C.4.2. Working calibration standard recipes.

C Std.	B-1 Std.	B-2 Std.
C-4 (Full scale)	20 ml	2 ml
	LNSW*	C-4 (Full scale)
C-1	30 ml	0 ml
C-2	20 ml	10 ml
C-3	10 ml	20 ml

B-1 Std.: Mixture of nitrate, phosphate and silicate.

B-2 Std.: Nitrite.

LNSW*: 22 ml milli-Q water in 250 ml volumetric flask, and LNSW add to marked line.

(4.4) Renewal of in-house standard solutions

In-house standard solutions as stated in (4.3) were renewed as shown in Table C.4.3.

Table C.4.3. Timing of renewal of in-house standards.

NO ₃ , NO ₂ , PO ₄ , Si	Renewal
A-1 Std. (NO ₃)	no renewal
A-2 Std. (NO ₂)	no renewal
A-3 Std. (PO ₄)	no renewal
A-4 Std. (Si)	commercial prepared solution
B Std.	
B-1 Std.	maximum 9 days
B-2 Std.	maximum 14 days
C Std.	Renewal
mixture of B-1 and B-2 Std.	Every measurement

B-1 Std.: Mixture of nitrate, phosphate and silicate.

B-2 Std.: nitrite.

(5) Use of RMNS

The reference material of nutrients in seawater (hereafter RMNS), which was prepared by the General Environmental Technos Co. Ltd. (Kanso Technos), was used every analysis at each hydrographic station. According to *Aoyama et al.* (2010), the RMNS homogeneity is 0.1 % - 0.2 % in high concentration range, and stability is 48 - 71 months. By the use of RMNSs for the analysis of seawater, it is expected to secure stable comparability and uncertainty of data. If RMNS will be certified in the future, the traceability of our analysis value will be secured. *Aoyama et al.* (2010) assigned nutrients concentrations for RMNS lot BA, AX, BE and AZ as shown in Table C.4.4.

Table C.4.4. INSS assigned concentration of RMNSs.

	Unit: $\mu\text{mol/kg}$		
	Nitrate	Phosphate	Silicate
RMNS-BA	0.07 ± 0.01	0.061 ± 0.007	1.61 ± 0.07
RMNS-AX	21.44 ± 0.05	1.614 ± 0.006	58.05 ± 0.12
RMNS-BE	36.70 ± 0.04	2.662 ± 0.005	99.20 ± 0.08
RMNS-AZ	42.36 ± 0.06	3.017 ± 0.005	133.93 ± 0.11

(5.1) RMNSs for this cruise

One hundred and five set of RMNS lots BA and BE were prepared to use every analysis at each hydrographic station. BA and BE were renewed every run. To check the inter-bottle consistency of RMNS, we re-measured the RMNS in the next analysis run. Sixteen of RMNS lots AX and AZ were prepared to use every 2 to 4 analysis and renewed every 2 or 3 runs in principle. The RMNS bottles were stored at a wet laboratory in the ship, where the temperature was maintained around 26 deg-C.

(5.2) Assigned concentration of RMNSs

We assigned nutrients concentrations for RMNS lots BA, AX, BE and AZ as shown in Table C.4.5 based on the analysis during the cruise. The measured concentration of RMNS lot BE during the cruise are shown in Figure C.4.6 - C.4.8 as quality control charts. The

concentration variations in these figures represent largely differences of the in-house standard. At Stn.25, one bottle of RMNS lot BE, No. 0138, showed obviously low concentrations. The measured values of all parameters were ca. 2% lower than expected. The concentrations of another bottle of RMNS lot BE, which was also analyzed in previous run, showed a good agreement with expected value. So, we neglected the result of No. 0138 of RMNS lot BE. At Stn.58, nitrate + nitrite concentration of BA No. 0756 had also shown unexpected low value, so it was neglected too.

The concentrations of RMNSs were in close agreement with expected values within the range of uncertainty except for the phosphate.

Table C.4.5. Assigned concentration of RMNSs.

	Unit: $\mu\text{mol/kg}$		
	Nitrate + Nitrite	Phosphate	Silicate
RMNS-BA	0.07 ± 0.03	0.02 ± 0.00	1.60 ± 0.10
RMNS-AX	21.89 ± 0.08	1.59 ± 0.01	58.14 ± 0.18
RMNS-BE	36.77 ± 0.11	2.64 ± 0.01	99.27 ± 0.19
RMNS-AZ	42.42 ± 0.13	2.98 ± 0.01	133.84 ± 0.23

Note: N(BA: Nitrate + Nitrite, Silicate)=104, N(BA: Phosphate)=105, N(BE: Nitrate + Nitrite, Phosphate)=104, N(BE: Silicate)=103, N(AX,AZ)=45.

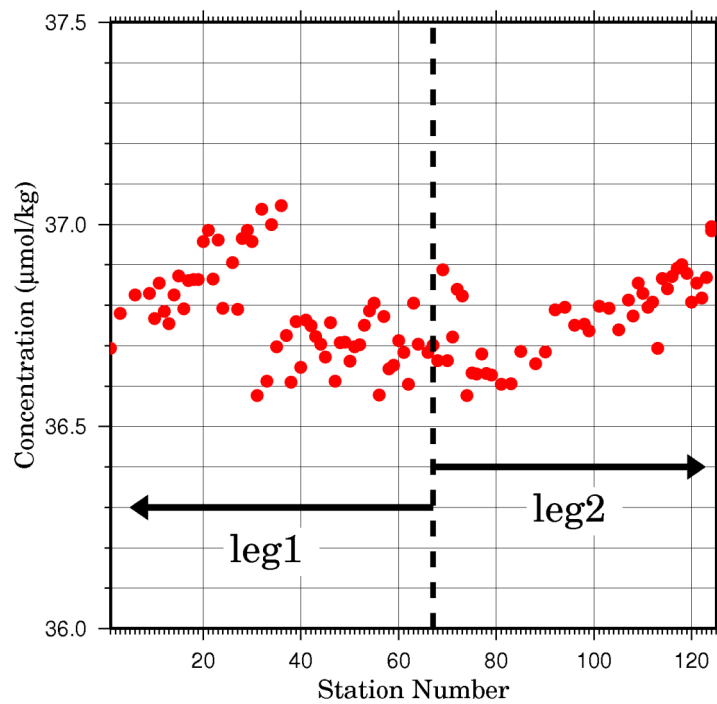


Figure C.4.6. Result of RMNS lot BE concentrations of nitrate + nitrite during the cruise.

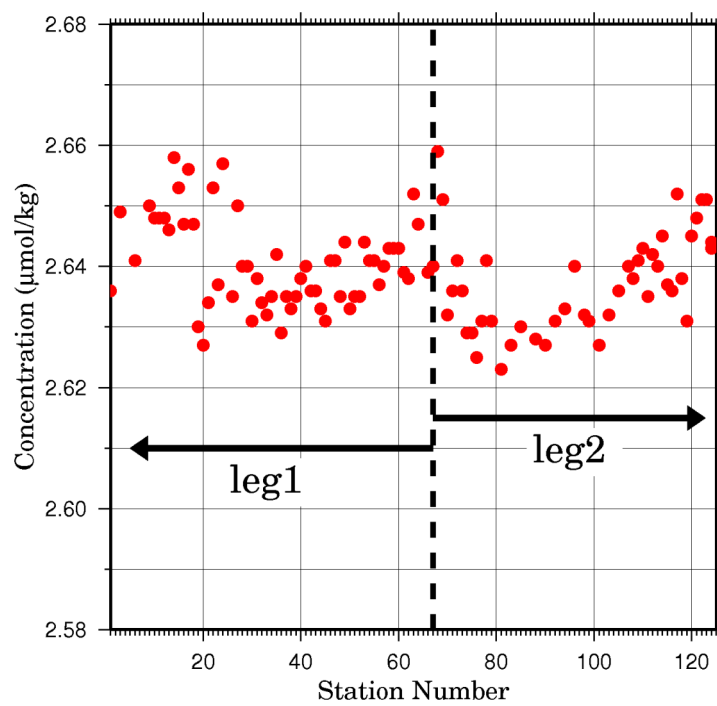


Figure C.4.7. Result of RMNS lot BE concentrations of phosphate during the cruise.

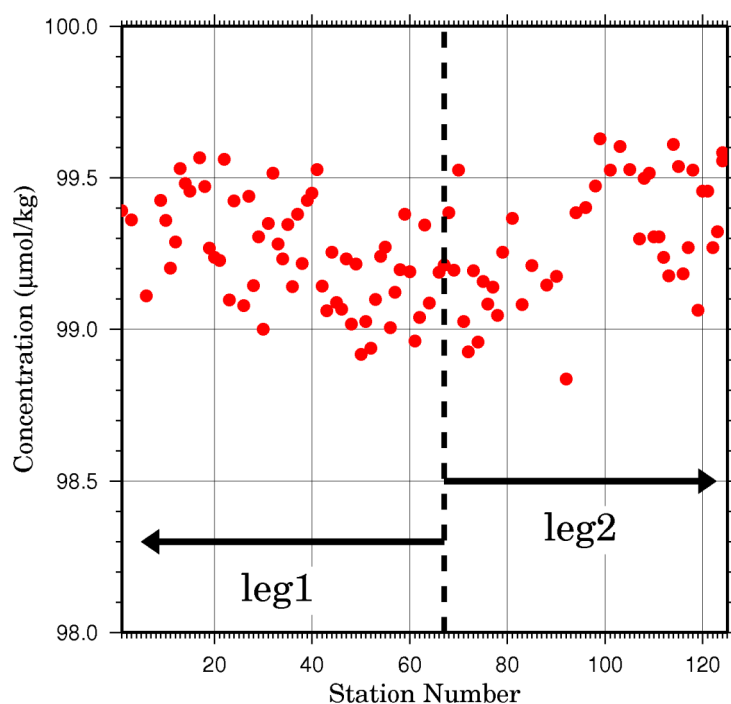


Figure C.4.8. Result of RMNS lot BE concentrations of silicate during the cruise.

(5.3) Relative standard deviation of RMNSs measurement

The relative standard deviation of lot BA, AX, BE and AZ throughout the cruise are shown in Table C.4.6.

Table C.4.6. Relative standard deviation of RMNSs lot BA, AX, BE and AZ measurements in each run throughout cruise.

	Nitrate + Nitrite	Phosphate	Silicate
	CV %	CV %	CV %
RMNS-BA	41.03	16.02	6.47
RMNS-AX	0.35	0.43	0.31
RMNS-BE	0.30	0.30	0.19
RMNS-AZ	0.31	0.31	0.17

Note: N(BA: Nitrate + Nitrite, Silicate)=104, N(BA: Phosphate)=105, N(BE: Nitrate + Nitrite, Phosphate)=104, N(BE: Silicate)=103, N(AX,AZ)=45.

(6) Quality control

(6.1) Precision of nutrients analyses during the cruise

Precision of nutrients analyses during the cruise was evaluated based on 5 or 6 measurements of the C-4 (full scale) standard in each run. Summary of precisions are shown in Table C.4.7. During this cruise, analytical precisions were 0.11 % for nitrate, 0.16 % for phosphate and 0.09 % for silicate in terms of mean of precision, respectively. The time series of precision are shown in Figure C.4.9 - C.4.11.

Table C.4.7. Summary of precisions during the cruise.

	Nitrate + Nitrite	Phosphate	Silicate
	CV %	CV %	CV %
Median	0.11	0.14	0.08
Mean	0.11	0.16	0.09
Maximum	0.32	0.38	0.31
Minimum	0.03	0.03	0.01
Number	105	105	104

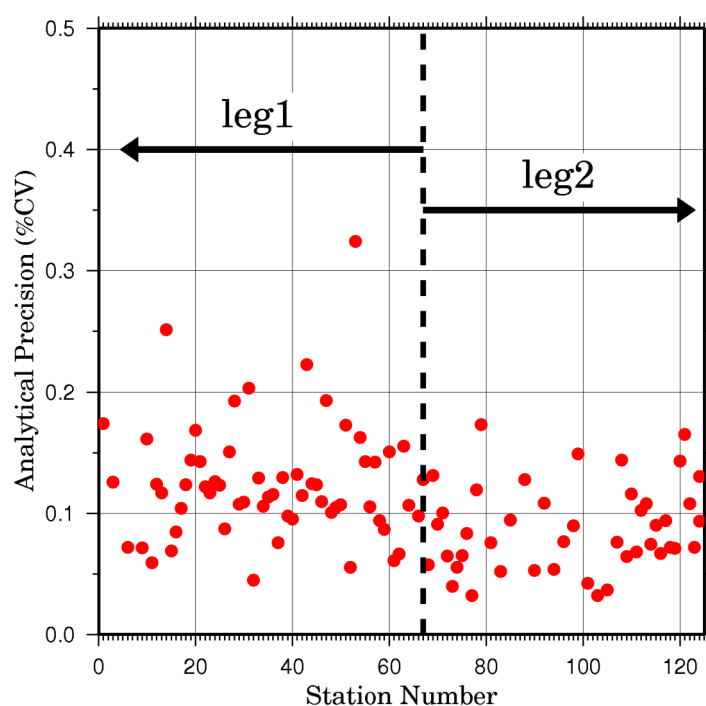


Figure C.4.9. Time series of precision of nitrate + nitrite.

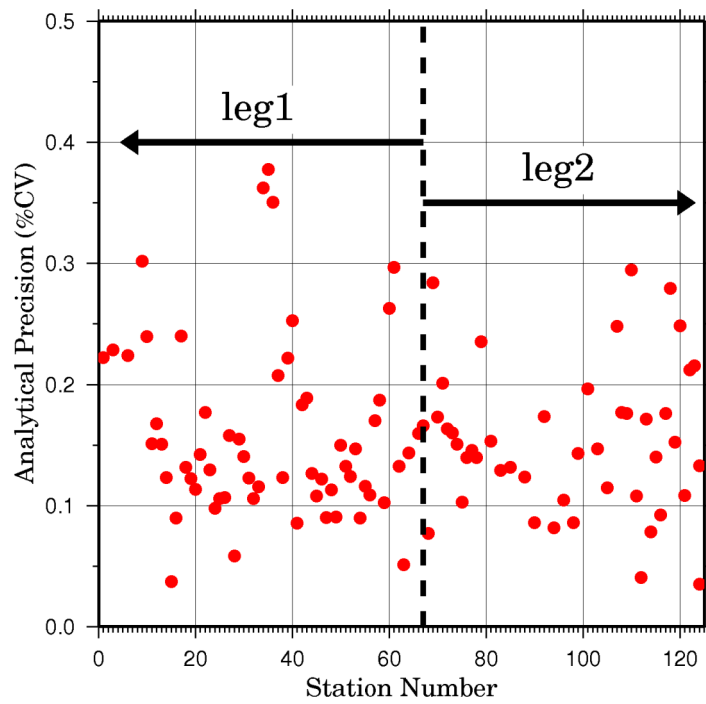


Figure C.4.10. Time series of precision of phosphate.

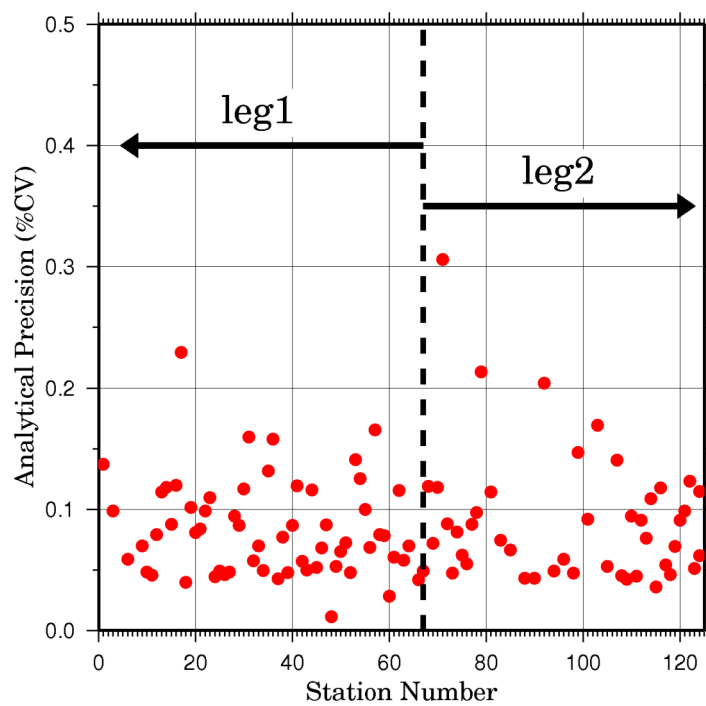


Figure C.4.11. Time series of precision silicate.

(6.2) Replicate sample measurement

Replicate samples were analyzed at every hydrographic station. Total amount of the replicate sample pairs was 405. Summary of replicate sample measurements are shown in Table C.4.8, and [Figure C.4.12 - C.4.14](#). During this cruise, the average difference and standard deviation of replicate measurement were 0.038 ± 0.036 $\mu\text{mol/kg}$ for nitrate + nitrite, 0.004 ± 0.004 $\mu\text{mol/kg}$ for phosphate and 0.140 ± 0.139 $\mu\text{mol/kg}$ for silicate, respectively.

Table C.4.8. Average difference of replicate samples in each run throughout cruise.

Unit: $\mu\text{mol/kg}$		
Nitrate + Nitrite	Phosphate	Silicate
0.038 ± 0.036	0.004 ± 0.004	0.140 ± 0.139

Note: N=403(nitrate, phosphate), N=399(silicate) at flag 2.

RF1005_NO₃ + NO₂ Result of Replicate Sampling (N=403)

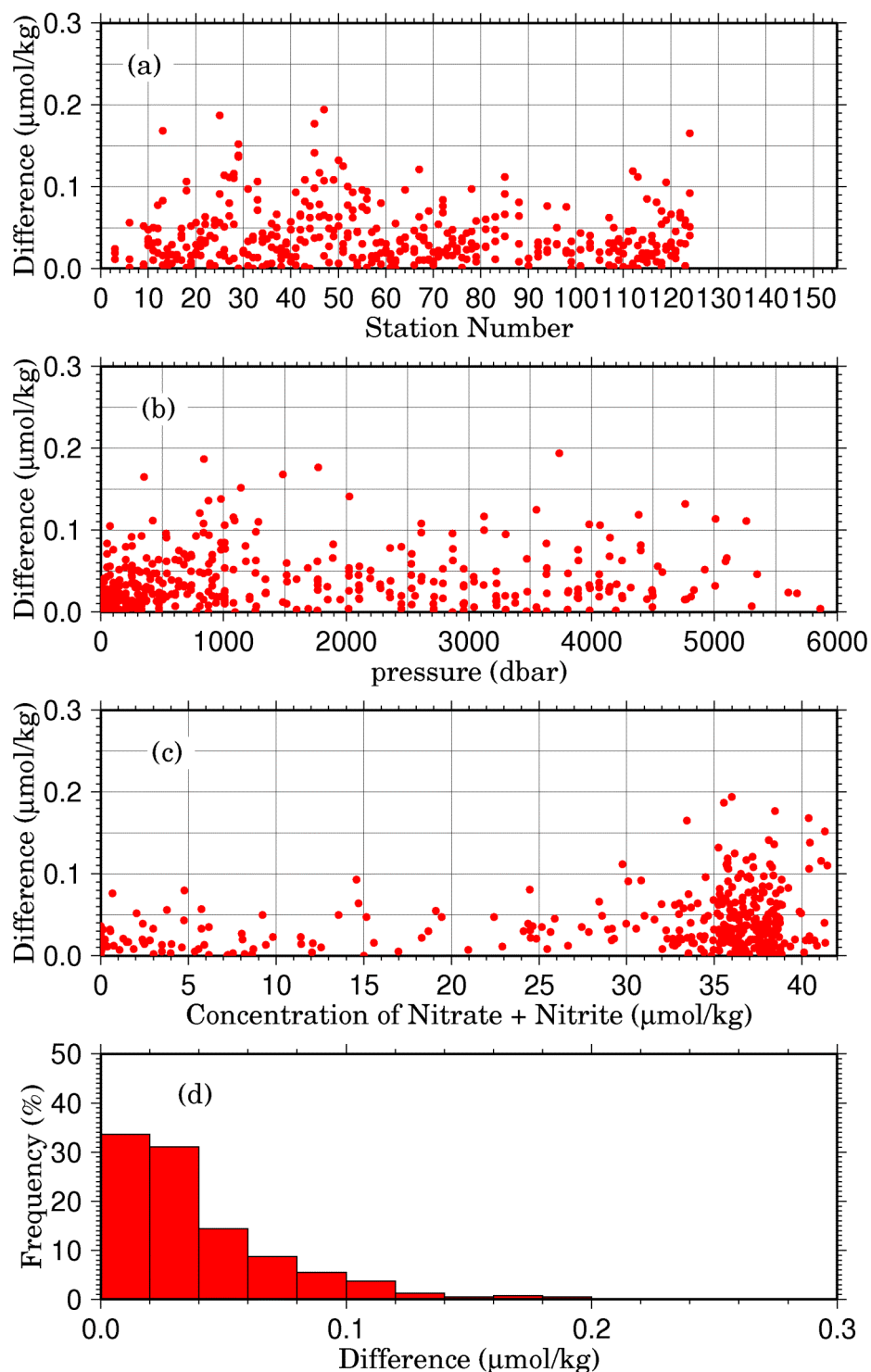


Figure C.4.12. Result of nitrate + nitrite replicate samplings (N=403) during RF10-05 against (a) station number, (b) sampling pressure, (c) concentration and (d) histogram of the result of replicate samplings.

RF1005_PO₄ Result of Replicate Sampling (N=403)

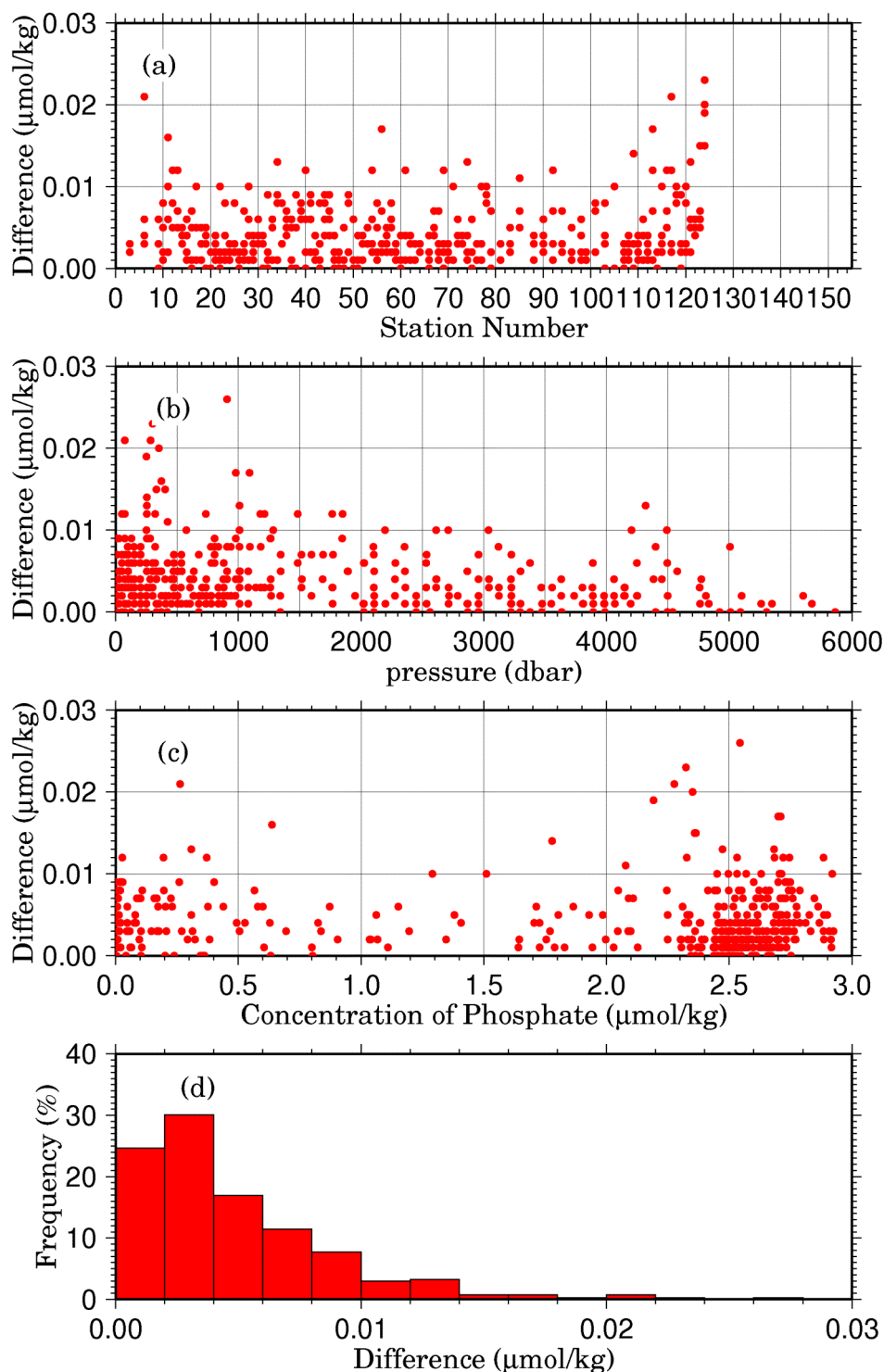


Figure C.4.13. Result of phosphate replicate samplings (N=403) during RF10-05 against (a) station number, (b) sampling pressure, (c) concentration and (d) histogram of the result of replicate samplings.

RF1005_SiO₂ Result of Replicate Sampling (N=399)

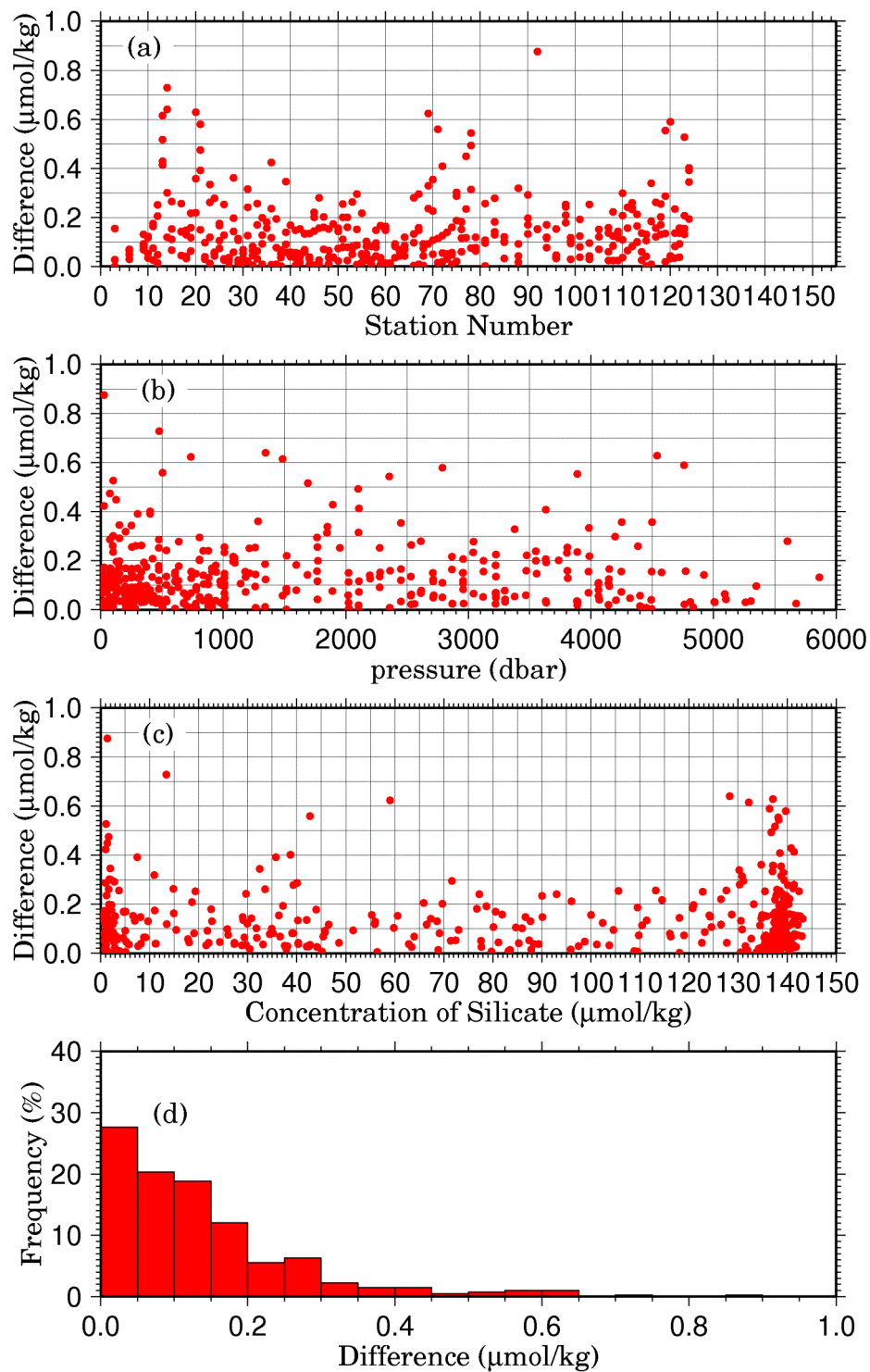


Figure C.4.14. Result of silicate replicate samplings (N=399) during RF10-05 against (a) station number, (b) sampling pressure, (c) concentration and (d) histogram of the result of replicate samplings.

(6.3) Duplicate sample measurement

Duplicate samples were analyzed at every hydrographic station. Total amount of the duplicate sample pairs was 295. Summary of duplicate sample measurements are shown in Table C.4.9, and [Figure C.4.15 - C.4.17](#). During this cruise, the average difference and standard deviation of replicate measurement were 0.040 ± 0.039 $\mu\text{mol/kg}$ for nitrate + nitrite, 0.005 ± 0.004 $\mu\text{mol/kg}$ for phosphate and 0.167 ± 0.163 $\mu\text{mol/kg}$ for silicate, respectively.

Table C.4.9. Average difference of duplicate samples in each run throughout cruise.

Unit: $\mu\text{mol/kg}$		
Nitrate + Nitrite	Phosphate	Silicate
0.040 ± 0.039	0.005 ± 0.004	0.167 ± 0.163

Note: N=293(nitrate + nitrite), N=290(phosphate), N=289(silicate) at flag 2.

RF1005_NO₃ + NO₂ Result of Duplicate Sampling (N=293)

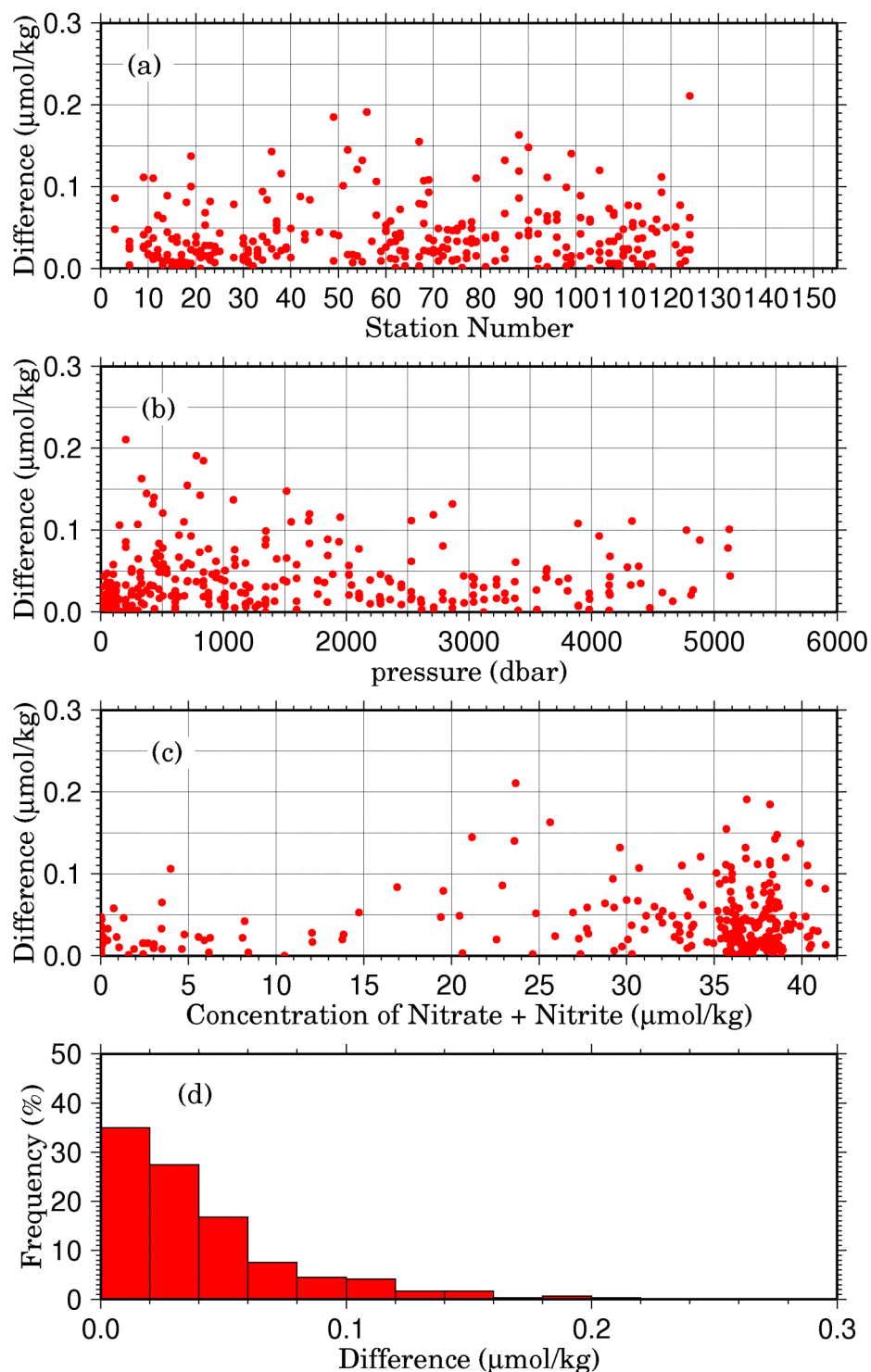


Figure C.4.15. Result of nitrate + nitrite duplicate samplings (N=293) during RF10-05 against (a) station number, (b) sampling pressure, (c) concentration and (d) histogram of the result of duplicate samplings.

RF1005_PO₄ Result of Duplicate Sampling (N=290)

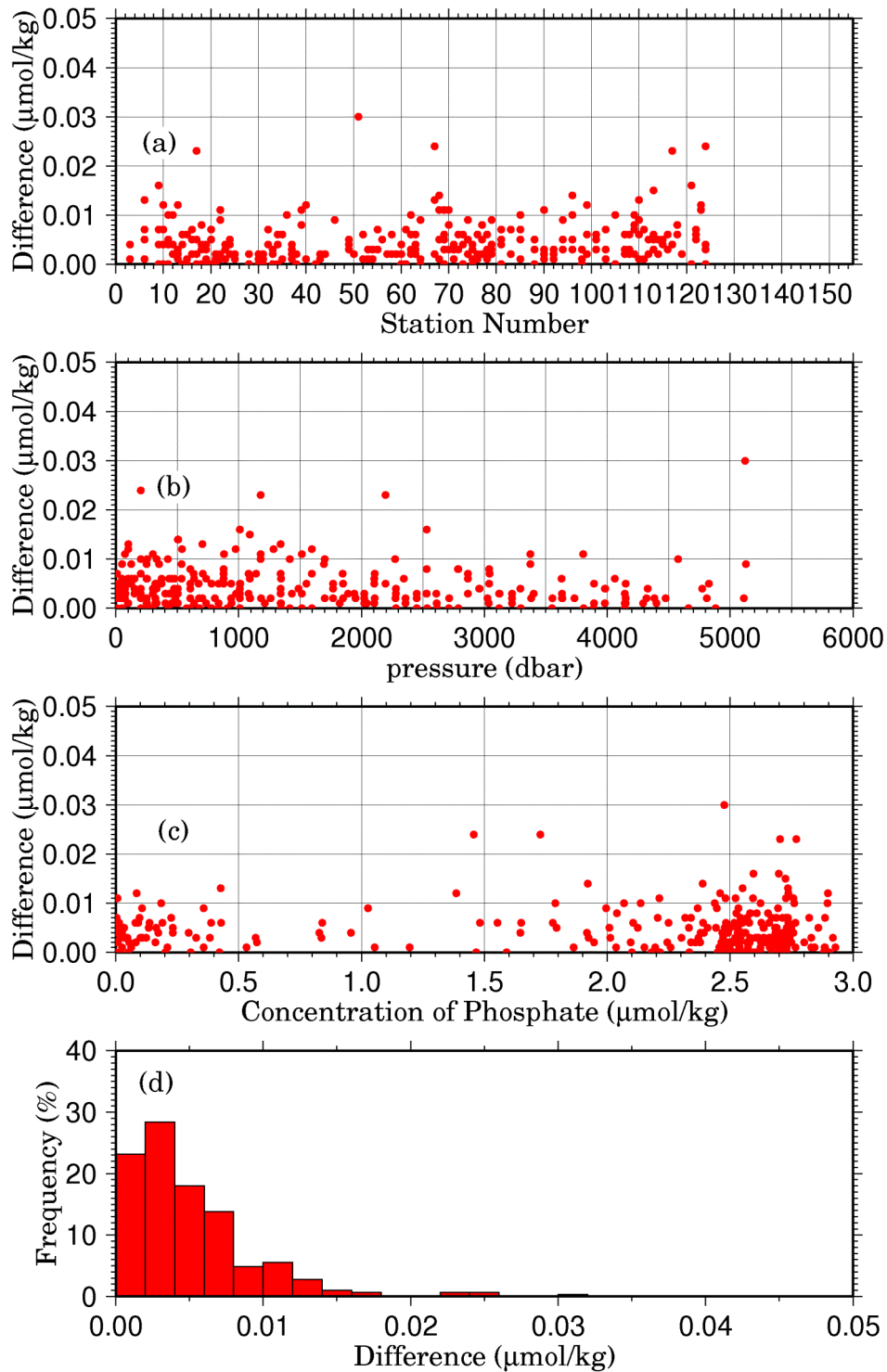


Figure C.4.16. Result of phosphate duplicate samplings (N=290) during RF10-05 against (a) station number, (b) sampling pressure, (c) concentration and (d) histogram of the result of duplicate samplings.

RF1005_SiO₂ Result of Duplicate Sampling (N=289)

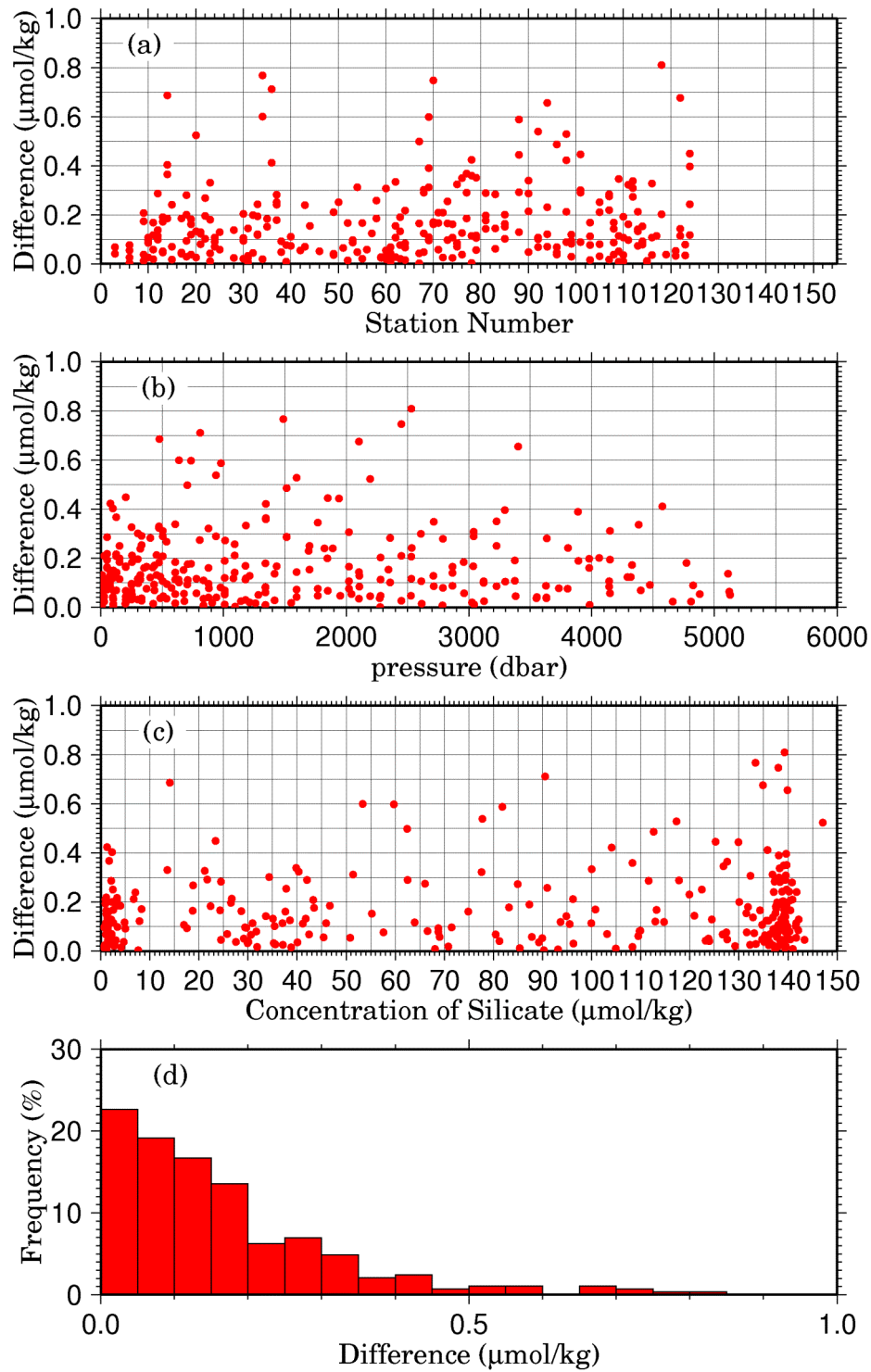


Figure C.4.17. Result of silicate duplicate samplings (N=289) during RF10-05 against (a) station number, (b) sampling pressure, (c) concentration and (d) histogram of the result of duplicate samplings.

(7) Uncertainty*

(7.1) Uncertainty of concentration level

The 44 sets of RMNS were analyzed during the cruise to get empirical equations to estimate uncertainty of concentrations of seawater samples throughout cruise. The average value and CV for each RMNS level were calculated, graphed, and a curve fit determined. The empirical equation (7.1) is an example of the curve fit between nutrients concentration C_x and the uncertainty at each concentration level.

$$\text{Uncertainty for parameter } X(\%) = a + b(1/C_x) + c(1/C_x)^2 \quad -- (7.1)$$

Where C_x is concentration of sample for parameter X.

Empirical equations, eqs. (7.2), (7.3) and (7.4) were used to estimate uncertainty of measurement of nitrate + nitrite, phosphate and silicate during this cruise. The equations are based on analysis of 44 sets of RMNS lots BA, AX, BE and AZ. [Figure C.4.18 – C.4.20](#) show graphic presentations of eqs. (7.2) - (7.4).

Nitrate + Nitrite Concentration C_n in $\mu\text{mol/kg}$:

Uncertainty of measurement of nitrate (%)=

$$0.274 + 1.779 \times (1/C_n) + 0.0497 \times (1/C_n)^2 \quad -- (7.2)$$

Where C_n is nitrate concentration of sample.

Phosphate Concentration C_p in $\mu\text{mol/kg}$:

Uncertainty of measurement of phosphate (%)=

$$0.166 + 0.416 \times (1/C_p) - 0.00146 \times (1/C_p)^2 \quad -- (7.3)$$

Where C_p is phosphate concentration of sample.

Silicate Concentration C_s in $\mu\text{mol/kg}$:

Uncertainty of measurement of silicate (%)=

$$0.0638 + 14.192 \times (1/C_s) - 5.753 \times (1/C_s)^2 \quad -- (7.4)$$

Where C_s is silicate concentration of sample.

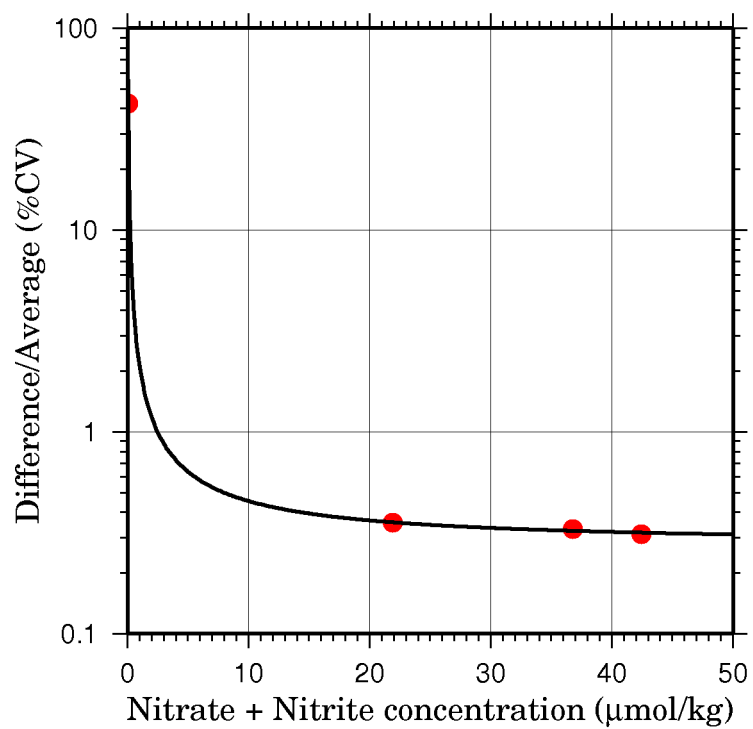


Figure C.4.18. Uncertainty of nitrate + nitrite concentration level.

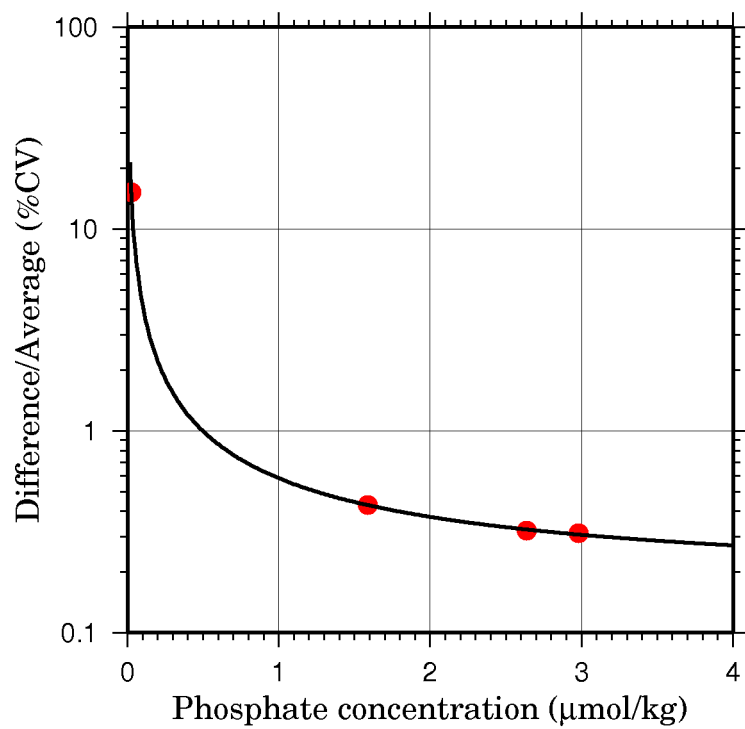


Figure C.4.19. Uncertainty of phosphate concentration level.

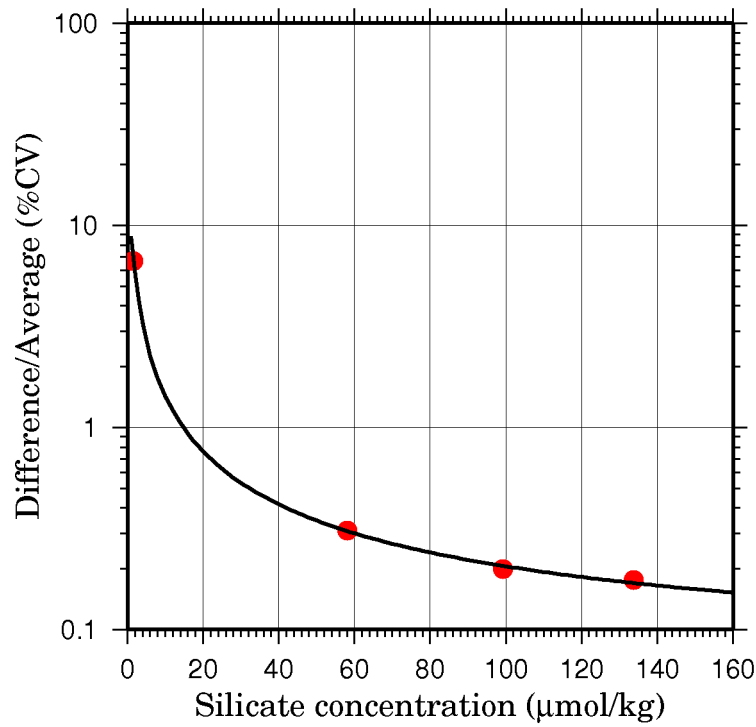


Figure C.4.20. Uncertainty of silicate concentration level.

(7.2) Uncertainty of analysis

Uncertainty of analysis is estimated relative standard deviation of precision throughout cruise as shown in subsection (6.1).

(7.3) Uncertainty of in-house standard

Uncertainty of in-house standard is estimated relative standard deviation of RMNS throughout cruise as shown in subsection (5.3).

(7.4) Combined relative standard uncertainty

Combined relative standard uncertainty is calculated equation (7.5).

$$\text{Combined relative standard uncertainty} = \sqrt{U_c^2 + U_a^2 + U_s^2 + U_r^2} \quad -- (7.5)$$

Where U_c is uncertainty of concentration level, U_a is uncertainty of analysis, U_s is uncertainty of in-house standard, U_r is uncertainty of RMNS. The result of giving the uncertainty by using eq. (7.5) for the decided RMNS concentration were shown [Table C.4.11](#).

Table C.4.11. Result of analysis value and expanded uncertainty obtained from measurements.

	Unit: $\mu\text{mol/kg}$		
	Nitrate + Nitrite	Phosphate	Silicate
RMNS-BA	0.07 \pm 0.07	0.02 \pm 0.01	1.60 \pm 0.31
RMNS-AX	21.89 \pm 0.24	1.59 \pm 0.02	58.14 \pm 0.54
RMNS-BE	36.77 \pm 0.33	2.64 \pm 0.02	99.27 \pm 0.57
RMNS-AZ	42.42 \pm 0.38	2.98 \pm 0.03	133.84 \pm 0.69

Note: coverage factor $k=2$

*The description of this section is based on that of *Aoyama et al.* (2009, unpublished manuscript).

(8) Problems/improvements occurred and solutions

During the cruise, low-frequency noise (ca. 6 seconds per cycle) in the all channel output of AA III. So moving average was applied to all the raw data.

At Stn.16 (Lat. 30°39.21'N / Long. 136°59.69'E, RF3664), the silicate output of quality control samples and sensitivity compensation sample had exceeded the maximum value of the instrument setting. It was impossible to process silicate data for the station properly, so we neglect it. Pump tubes were replaced after the analysis.

Due to a problem on Phosphate data at Stn.36 (Lat. 20°59.83'N / Long. 136°58.21'E, RF3684), we had done another analytical run for the station. To reduce the analysis time, we omitted the C-2 and C-3 standard on these run, and processed the data as described below.

1. For each phosphate standard measurement in every run except for Stn.36, calculate the difference dC_x between the concentration (C_{x2}) based on quadratic calibration equation and the concentration (C_{x1}) based on linear calibration equation.

2. Calculate mean and standard deviation of dC_x at each level (C-1, C-2, C-3 and C-4) and reject the data for individual run if any of dC_x at each level exceeds the range of $\text{mean} \pm \text{standard deviation}$.

3. The correction equation (8.1) is calculated by the regression analysis using all QCed pair of dC_x and C_{x1} .

$$dC_x(C_{x1}) = a + bC_{x1} + cC_{x1}^2 \quad \text{-- (8.1)}$$

4. For phosphate of Stn.36, calculate tentative sample concentrations C_{t1} based on linear calibration equation in each run.

5. The sample concentration C is obtained from equation (8.2) using C_{t1} and eq. (8.1).

$$C = C_{t1} + dC_x(C_{t1}) \quad \text{-- (8.2)}$$

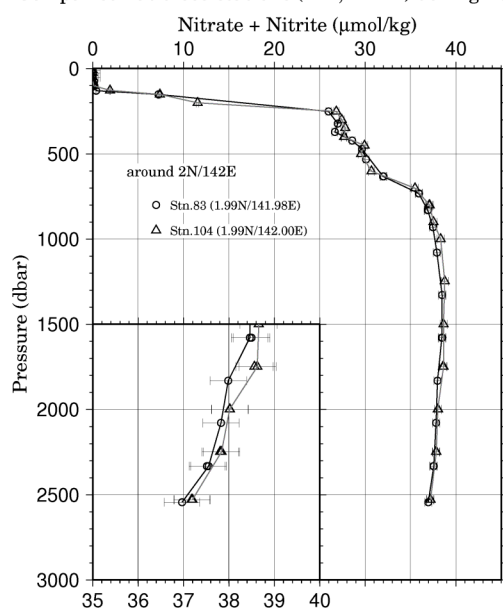
The correction term dC_x represents non-linearity of standard calibration. The correction for phosphate at Stn.36 was smaller than $0.003 \mu\text{mol/kg}$.

(9) Results

(9.1) Comparison at cross-stations during this cruise

Cross-stations during this cruise were two stations. The one was located at $2^\circ\text{N}/142^\circ\text{E}$, another was located $7^\circ\text{N}/137^\circ\text{E}$. At stations of Stn.83 (RF3731) and Stn.104 (RF3755), hydrocast sampling for nutrients (nitrate, nitrite, phosphate, silicate) were conducted two times at interval of about five days. Each nutrients parameter profiles of the two hydrocasts agreed well within the range of uncertainty when correcting it by using RMNS. At stations of Stn.67 (RF3715), Stn.68 (RF3716) and Stn.124 (RF3772), hydrocast sampling for nutrients were conducted three times. Interval between the first and the second was about a week, interval between the second and the third was about two weeks. Each nutrients parameter profiles of the three hydrocasts agreed well within the range of uncertainty when correcting it by using RMNS. These profiles are shown in [Figure C.4.21 - C.4.23](#).

Comparison at cross-stations (2°N, 142°E) during P9 revisit



Comparison at cross-stations (7°N, 137°E) during P9 revisit

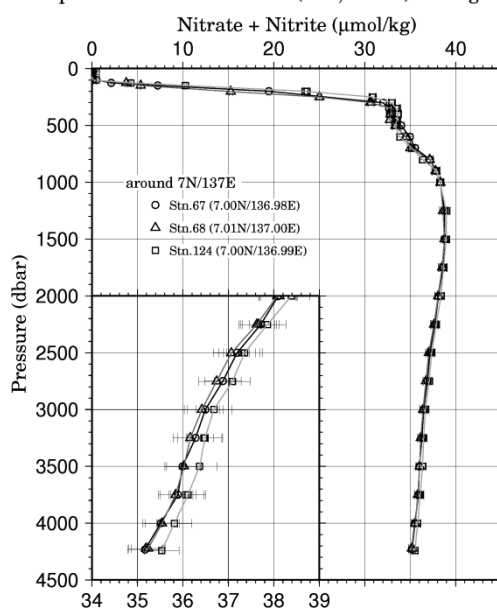
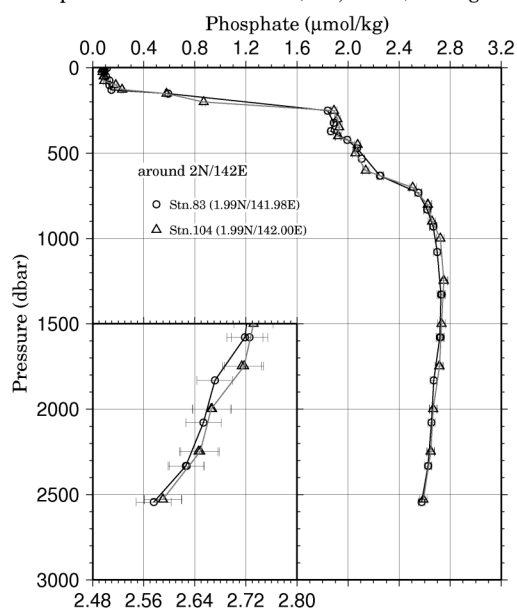


Figure C.4.21. Comparison of nitrate +nitrite profiles between the first hydrocast (circle) and the second one (triangle) at the cross-stations of 2°N/142°E (left), and the first hydrocast (circle), the second one (triangle) and the third one (square) at the cross-stations of 7°N/137°E (right).

Comparison at cross-stations (2°N, 142°E) during P9 revisit



Comparison at cross-stations (7°N, 137°E) during P9 revisit

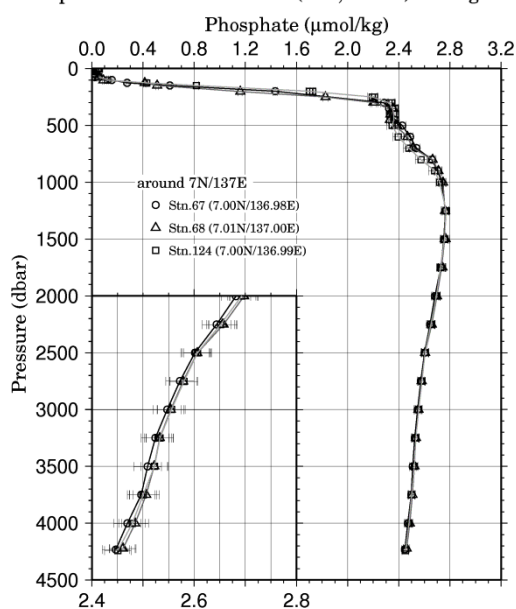
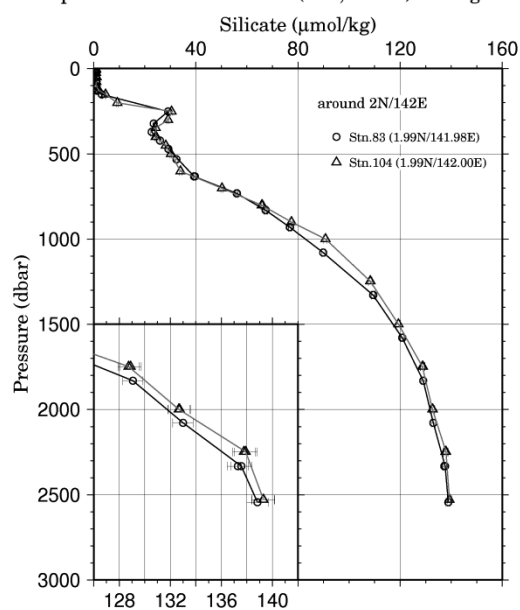


Figure C.4.22. Comparison of phosphate profiles between the first hydrocast (circle) and the second one (triangle) at the cross-stations of 2°N/142°E (left), and the first hydrocast (circle), the second one (triangle) and the third one (square) at the cross-stations of 7°N/137°E (right).

Comparison at cross-stations (2°N, 142°E) during P9 revisit



Comparison at cross-stations (7°N, 137°E) during P9 revisit

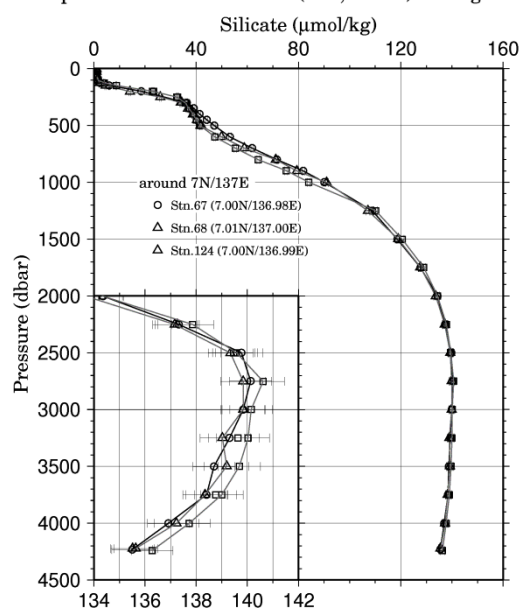


Figure C.4.23. Comparison of silicate profiles between the first hydrocast (circle) and the second one (triangle) at the cross-stations of 2°N/142°E (left), and the first hydrocast (circle), the second one (triangle) and the third one (square) at the cross-stations of 7°N/137°E (right).

(9.2) Comparison at cross-stations of WHP-P2 section in 2004 and WHP-P9 in 1994

We compared our nutrients data with gridded data of WHP-P2 at a cross point around 30°N/137°E. WHP-P2 line was observed two times, the repeat cruise was observed in 2004 by *R/V Melville* belonged to Scripps Institution of Oceanography (SIO). WHP-P9 line was observed in 1994 by JMA. These data may have inter-cruise differences because they did not measure the RMNS in their cruise. Summary of compared these data profiles shown in Figure C.4.24 - C.4.26.

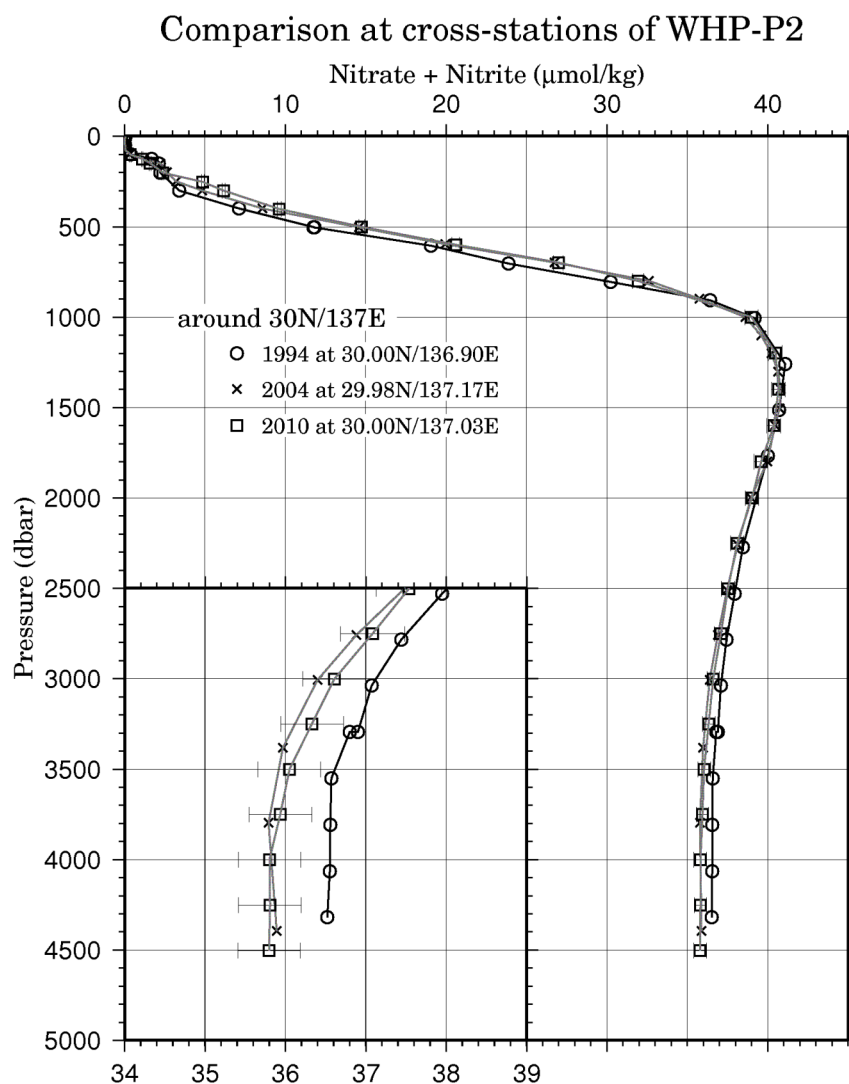


Figure C.4.24. Comparison of nitrate + nitrite profiles at cross-station of WHP-P2. Circle, plus, square show the WHP-P9 in 1994 by JMA, WHP-P2 in 2004 by SIO and WHP-P9 revisit in 2010 by JMA, respectively.

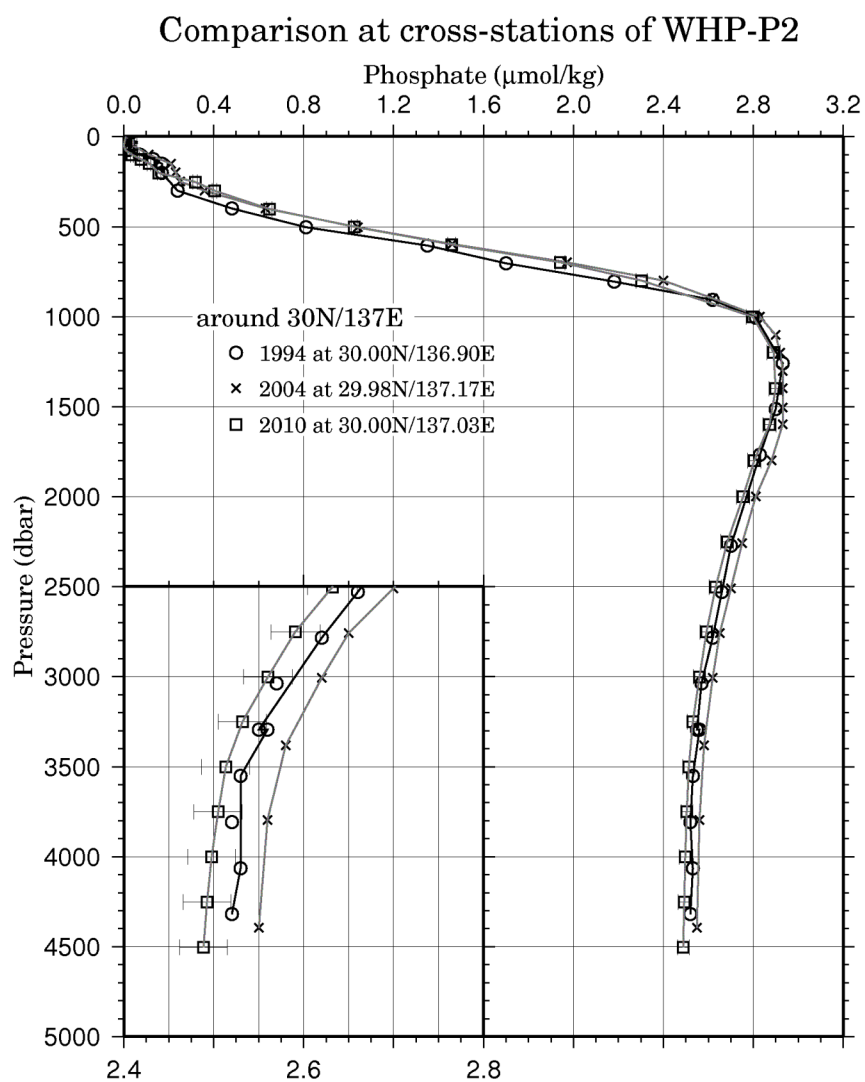


Figure C.4.25. Comparison of phosphate profiles at cross-station of WHP-P2. Circle, plus, square show the WHP-P9 in 1994 by JMA, WHP-P2 in 2004 by SIO and WHP-P9 revisit in 2010 by JMA, respectively.

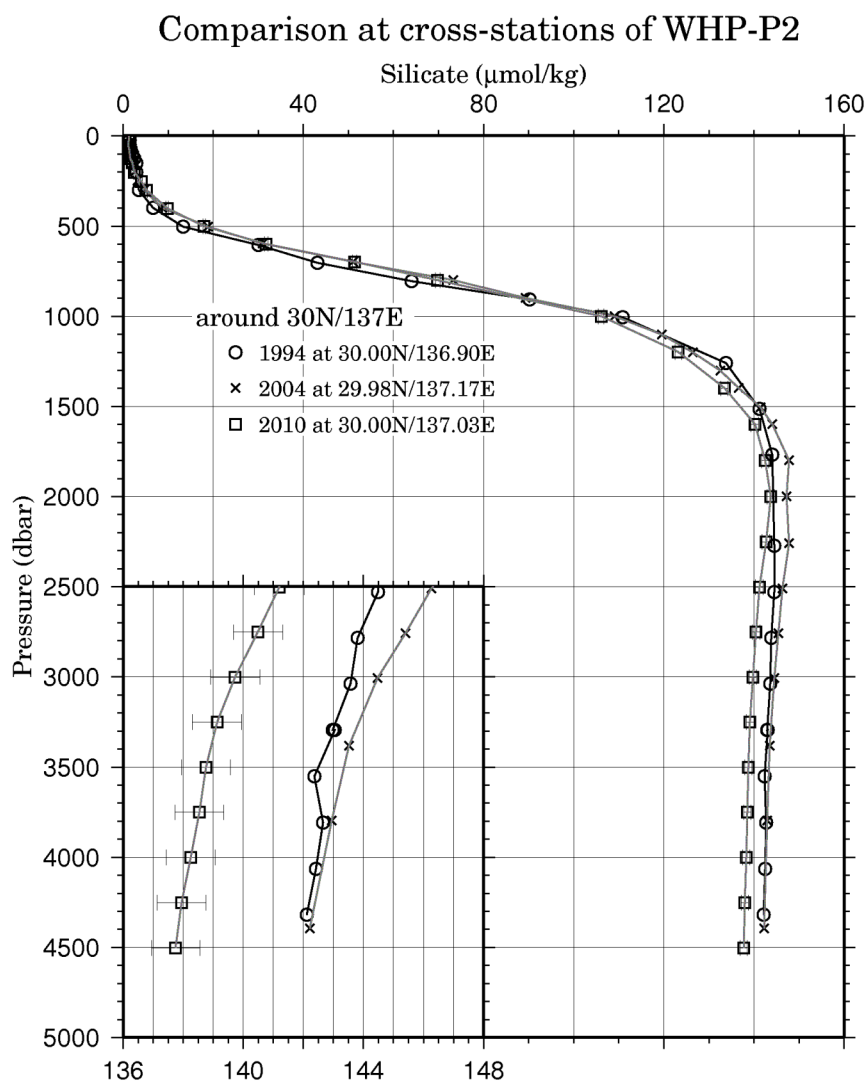


Figure C.4.26. Comparison of silicate profiles at cross-station of WHP-P2. Circle, plus, square show the WHP-P9 in 1994 by JMA, WHP-P2 in 2004 by SIO and WHP-P9 revisit in 2010 by JMA, respectively.

(9.3) Comparison at cross-stations of WHP-P3 section in 1985, 2005/06 and WHP-P9 in 1994

We compared our nutrients data with gridded data of WHP-P3 at a cross point around 24°N/137°E. WHP-P3 line was observed two times, the first was observed in 1985 by *R/V Thomas G. Thompson* belonged to SIO and the repeat cruise was observed in 2005/06 by *R/V Mirai* belonged to Japan Agency for Marine-Earth Science and Technology (JAMSTEC, 2007). WHP-P9 line was observed in 1994 by JMA. Our nutrients data at P9 revisit and JAMSTEC data in 2005/06 are comparable directly through the RMNS. However, SIO data in 1985 and JMA data in 1994 may have inter-cruise differences because they did not measure the RMNS in their cruise. Summary of compared these data profiles shown in [Figure C.4.27 - C.4.29](#).

Note: Silicate data of WHP-P3 revisit (JAMSTEC, 2007) is corrected by a scale factor provided by M. Aoyama, PI of nutrients of the cruise (personal communication).

Comparison at cross-stations of WHP-P3

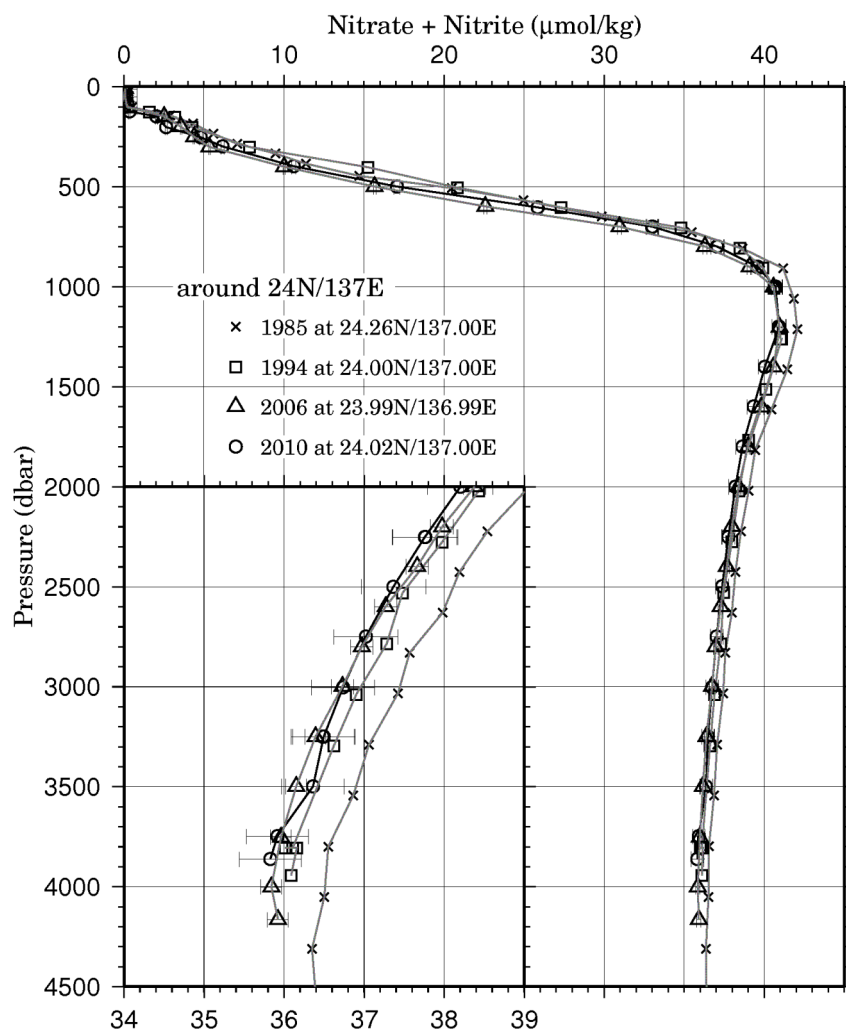


Figure C.4.27. Comparison of nitrate + nitrite profiles at cross-station of WHP-P3. Plus, square, triangle, circle show the WHP-P3 in 1985 by SIO, WHP-P9 in 1994 by JMA, WHP-P3 in 2005/06 by JAMSTEC and WHP-P9 revisit in 2010 by JMA, respectively.

Comparison at cross-stations of WHP-P3

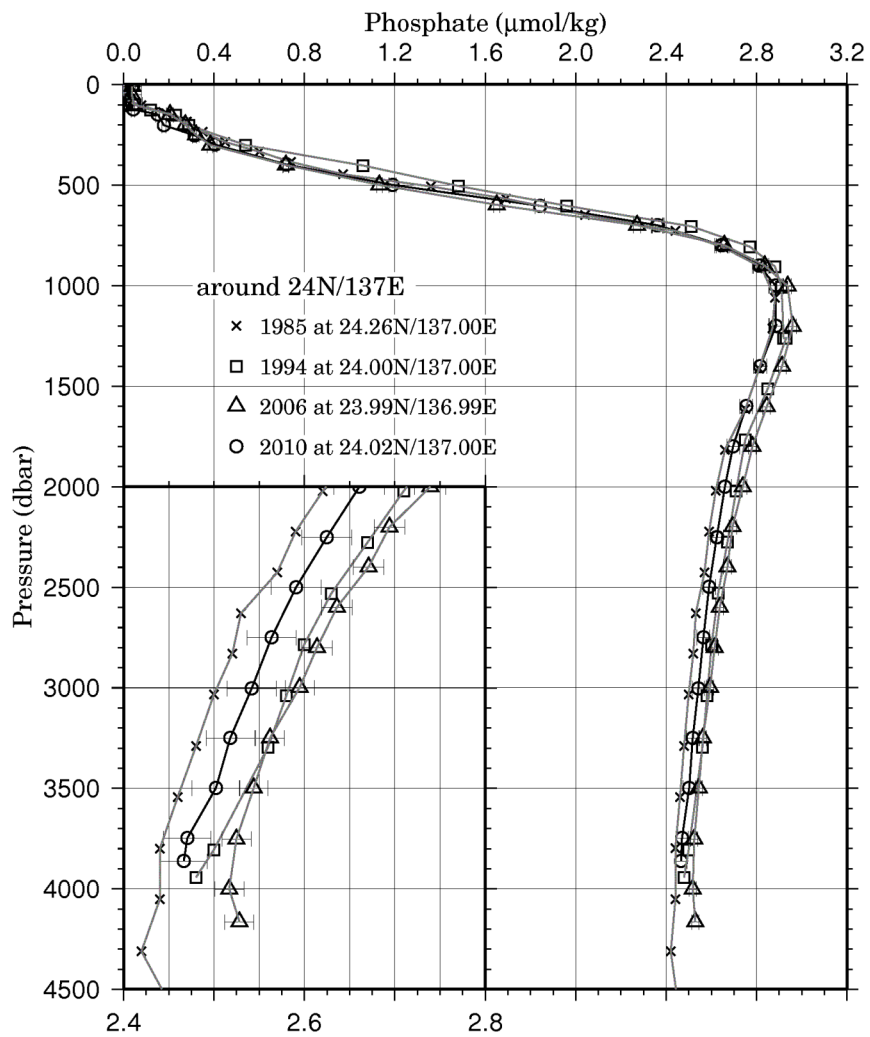


Figure C.4.28. Comparison of phosphate profiles at cross-station of WHP-P3. Plus, square, triangle, circle show the WHP-P3 in 1985 by SIO, WHP-P9 in 1994 by JMA, WHP-P3 in 2005/06 by JAMSTEC and WHP-P9 revisit in 2010 by JMA, respectively.

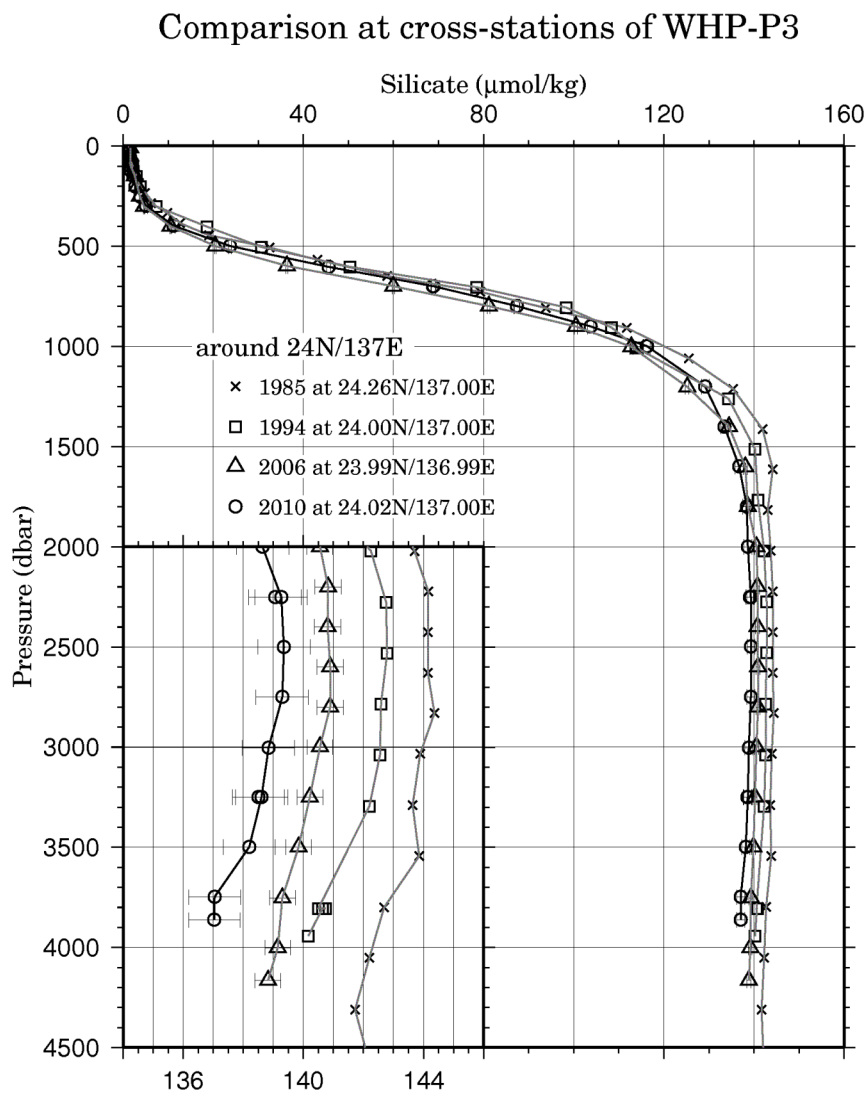


Figure C.4.29. Comparison of silicate profiles at cross-station of WHP-P3. Plus, square, triangle, circle show the WHP-P3 in 1985 by SIO, WHP-P9 in 1994 by JMA, WHP-P3 in 2005/06 by JAMSTEC and WHP-P9 revisit in 2010 by JMA, respectively. Data of WHP-P3 revisit (JAMSTEC, 2007) is corrected by a scale factor provided by M. Aoyama, PI of nutrients of the cruise (personal communication).

(9.4) Comparison at cross-stations of WHP-P4 section in 1989, and WHP-P9 in 1994

We compared our nutrients data with gridded data of WHP-P4 at cross point around 9°N/137°E. WHP-P4 line was observed in 1989 by *R/V Moan Wave* belonged to University of Hawaii (UH). WHP-P9 line was observed 1994 by JMA. These data may have inter-cruise differences because they did not measure the RMNS in their cruise. Summary of compared these data profiles shown in Figure C.4.30 - C.4.32.

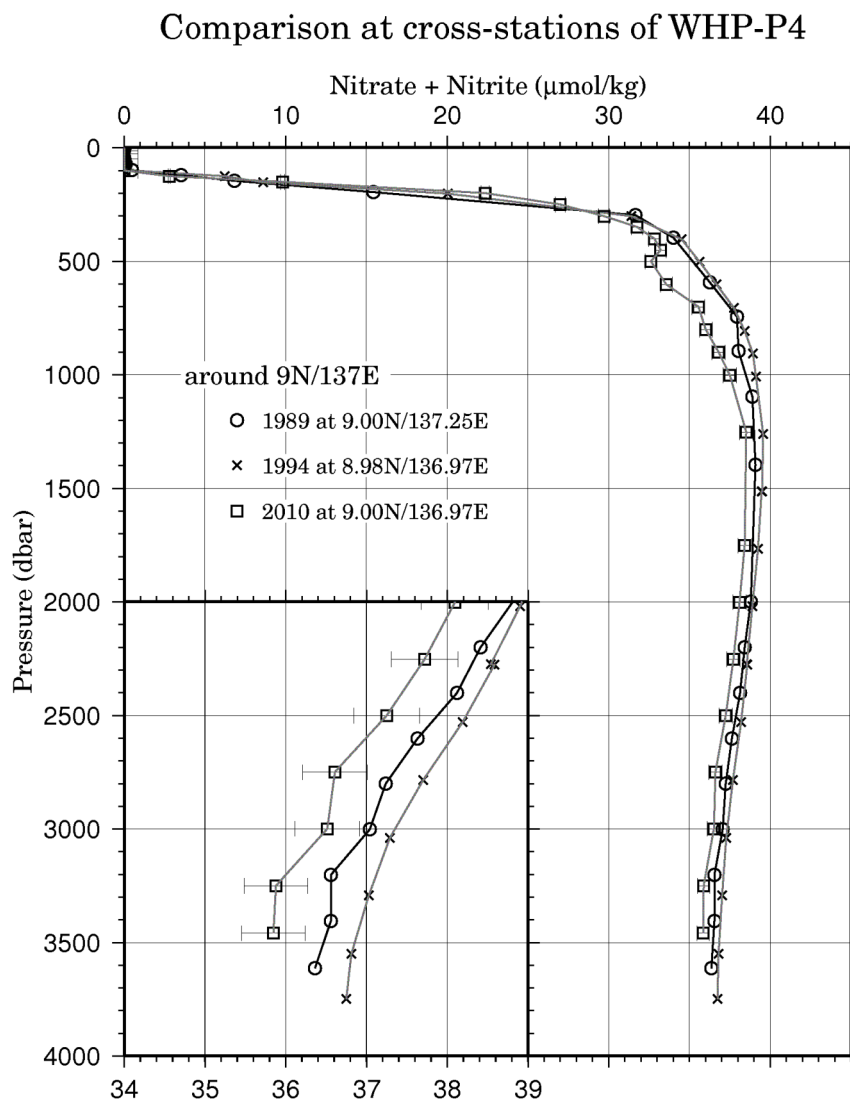


Figure C.4.30. Comparison of nitrate + nitrite profiles at cross-station of WHP-P4. Circle, plus, square show the WHP-P4 in 1989 by UH, WHP-P9 in 1994 by JMA and WHP-P9 revisit in 2010 by JMA, respectively.

Comparison at cross-stations of WHP-P4

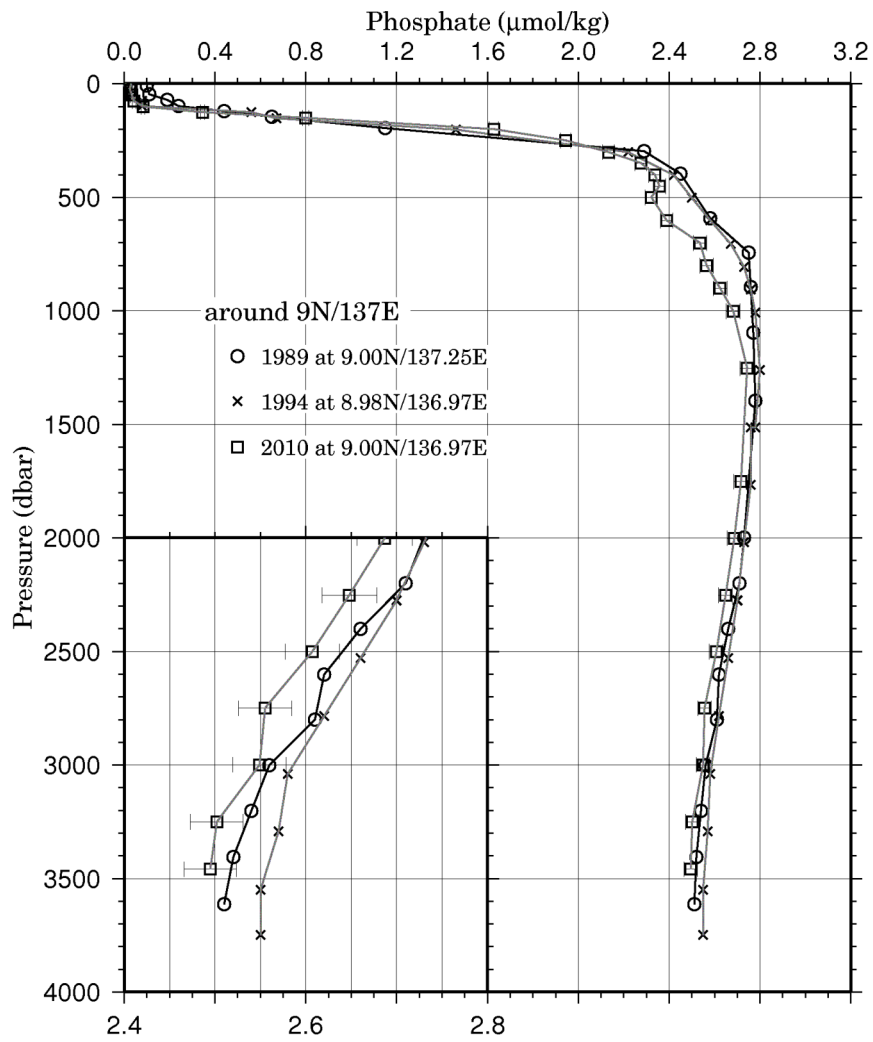


Figure C.4.31. Comparison of phosphate profiles at cross-station of WHP-P4. Circle, plus, square show the WHP-P4 in 1989 by UH, WHP-P9 in 1994 by JMA and WHP-P9 revisit in 2010 by JMA, respectively.

Comparison at cross-stations of WHP-P4

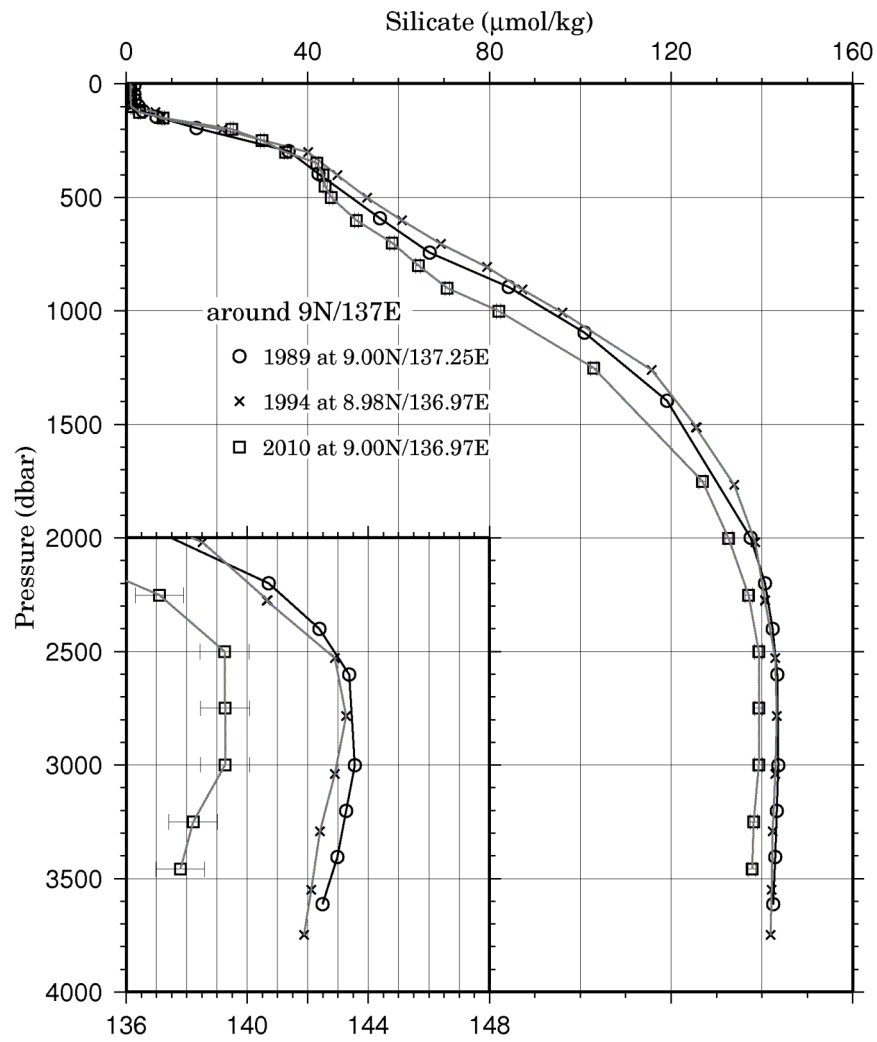


Figure C.4.32. Comparison of silicate profiles at cross-station of WHP-P4. Circle, plus, square show the WHP-P4 in 1989 by UH, WHP-P9 in 1994 by JMA and WHP-P9 revisit in 2010 by JMA, respectively.

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8. *Phytopigment (chlorophyll-a and phaeopigments)*

(1) Personnel

Yusuke Takatani (GEMD/JMA)

Shinichiro Umeda (GEMD/JMA)

(2) Station occupied

A total of 50 stations (Leg 1: 29, Leg 2: 21) were occupied for phytopigment. Station location and sampling layers of phytopigment are shown in Figure C.9.1.

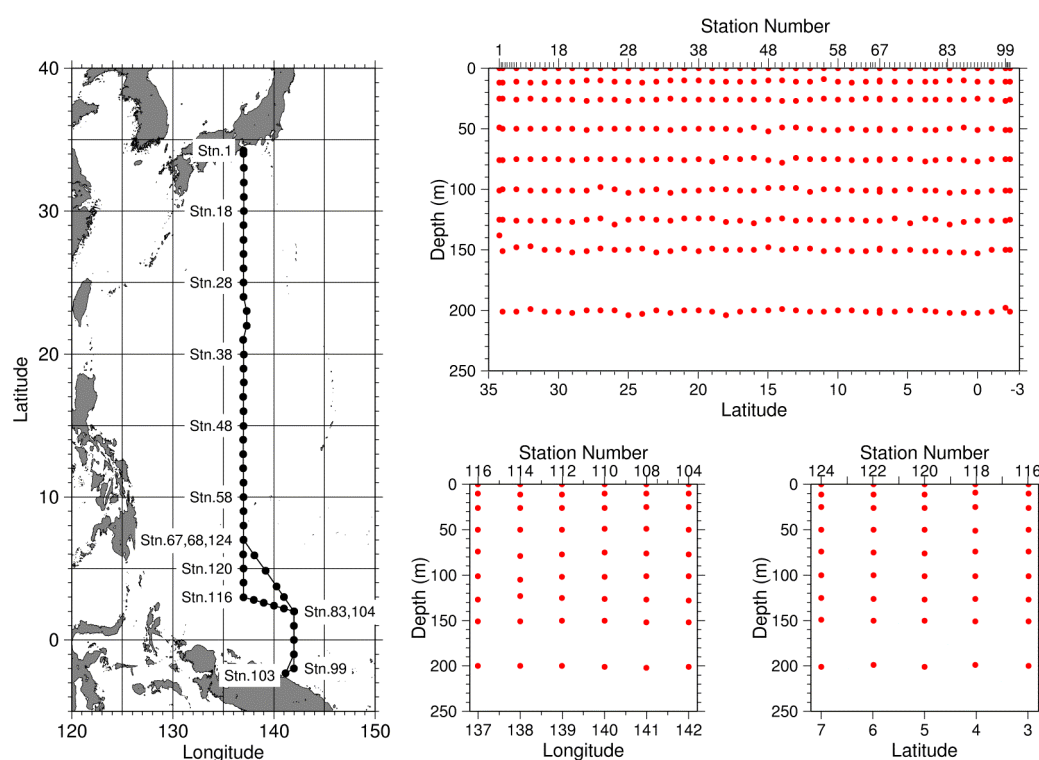


Figure C.9.1. Station location (left panel) and sampling layers of phytopigment (right panels).

(3) Reagents

N,N-dimethylformamide (DMF)

0.5 N hydrochloric acid (0.5N HCl)

Chlorophyll-*a* standard from *Anacystis nidulans* algae (Lot. BCBB4166) manufactured by Sigma Chemical Co.

Rhodamine WT manufactured by Turner Designs.

(4) Instruments

Fluorometer; 10-AU (S/N:6718) manufactured by Turner Designs

Spectrophotometer; UV-1800 (S/N:A114547) manufactured by Shimadzu Co. Ltd.

Glass Fiber Filter; Whatman GF/F filter (25 mm)

(5) Standardization

A chlorophyll-*a* standard calibration for fluorometric determination was performed by the method described by *UNESCO* (1994). Before standardization, fluorometer was calibrated by using 100 % DMF and a Rhodamine solution diluted to 1ppm with deionized water. Chlorophyll-*a* standard was dissolved in DMF. The concentration of chlorophyll-*a* solution was determined spectrophotometrically as follows;

$$\text{Chl } a \text{ concentration } (\mu\text{g/ml}) = A_{\text{chl}} / \text{specific absorption coefficient}$$

where A_{chl} is the difference between absorbance at 663.8 nm and 750 nm. The specific absorption coefficient is 88.74 L/g·cm (*Porra et al.*, 1989). Using this precise chlorophyll-*a* concentration, the linear calibration factor (f_{ph}) and the acidification coefficient (R) were calculated. f_{ph} was calibrated for each cuvette as the slope of the unacidified fluorometric reading vs. chlorophyll-*a* concentration calculated spectrophotometrically. R was calculated by averaging the ratio of the unacidified and acidified readings of pure chlorophyll-*a*. Table C.9.1 shows f_{ph} and R in this cruise.

Table C.9.1. f_{ph} and R determined by the standardization.

Linear calibration factor (f_{ph})	5.13
Acidification coefficient (R)	1.848

(6) Seawater sampling and measurement

Seawater samples were collected from 10-liters Niskin bottle attached the CTD-system and a stainless steel bucket for the surface in 200 ml. The seawater samples were immediately filtered through 25 mm GF/F filter by low vacuum pressure, and the particulate matter was made to adsorb to the filter. The filter was put into the vial containing 9 ml of DMF, then stored to extract phytopigment in the refrigerator for more than 24 hours at –30 deg-C until analysis.

After the extracts were put on the room temperature for at least one hour in the dark, only the extracts except the filter were decanted from the vial to the cuvette. Fluorometer readings for each cuvettes were taken before and after acidification with 1-2 drops 0.5 N HCl. Chlorophyll-*a* (Chl) and phaeopigment (Phaeo) concentration in the sample are calculated using the following equations;

$$\text{Chl } (\mu\text{g/l}) = \frac{F_0 - F_a}{f_{ph} \cdot (R - 1)} \cdot \frac{v}{V}$$

$$\text{Phaeo } (\mu\text{g/l}) = \frac{R \cdot F_0 - F_a}{f_{ph} \cdot (R - 1)} \cdot \frac{v}{V}$$

F_0 = reading before acidification

F_a = reading after acidification

R = acidification coefficient (F_0/F_a) for pure chlorophyll-*a*

f_{ph} = linear calibration factor

v = extraction volume

V = sample volume

(7) Quality control flag assignment

Quality flag values were assigned to phytopigment measurements using the code defined in IOCCP Report No.14 (*Swift*, 2010). Measurement flags of 2 (good), 3 (questionable), and 4 (bad) have been assigned ([Table C.9.2](#)).

Table C.9.2. Summary of assigned quality control flags.

Flag	Definition	Chl	Phaeo
2	Good	437	437
3	Questionable	0	0
4	Bad (Faulty)	12	12
Total number		449	449

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9. Lowered Acoustic Doppler Current Profiler

(1) Personnel

Tetsuya NAKAMURA (GEMD/JMA)

Yoshikazu HIGASHI (GEMD/JMA)

Tomoyuki KITAMURA (GEMD/JMA)

Takahiro SEGAWA (GEMD/JMA)

Keizo SHUTTA (GEMD/JMA)

Yasuaki BUNGI (GEMD/JMA)

(2) Instrument and measurement

Direct flow measurement from sea surface to the bottom was carried out using a Lowered Acoustic Doppler Current Profiler (LADCP). The instrument used was the RDI Workhorse Monitor 307.2 kHz unit (S/N 13666; Teledyne RD Instruments, USA). The instrument was attached on the CTD frame, orientating downward. The CPU firmware version was 50.36.

One ping raw data were recorded. Settings for the collecting data were as listed in Table C.9.1. A total of 124 operations were made with the CTD observations. The performance of the LADCP was good between Stn.1 (RF3649) and Stn.42 (RF3690). From Stn.43 (RF3691) the echo intensity of beam 4 got weak, and from Stn.50 (RF3698) it might be broken down. From Stn.109 (RF3757), the beam 1 might be also broken down. And besides, data transfer errors often occurred during download process from the LADCP to the PC. So the data processing was performed for 101 stations.

Table C9.1. Setting for the correcting data.

Bin length	8m
Bin number	25
Error Threshold	2000mm/s
Ping interval	1.0sec

(3) Data process and result

Vertical profiles of velocity are obtained by the inversion method (*Visbeck, 2002*). Both the up and down casts are used for the inversion. Since the first bin from LADCP is influenced by the turbulence generated by CTD frame, the weight for the inversion is set to small value of 0.1. The GPS navigation data are used in the calculation of the reference velocities and the bottom-track data are used for the correction of the reference velocities. Shipboard ADCP (SADCP) data averaged for 5 minutes are also included in the calculation. The CTD data are used for the sound speed and depth calculation. IGRF (International Geomagnetic Reference Field) 11th generation data are used for calculating magnetic deviation to correct the direction of velocity. In the processing, we use Matlab routines (version 8b: 5 April 2004) provided by M. Visbeck and G. Krahmann. We set the weight for SADCP data in the calculation to 3.0, so vertical profiles of velocity obtained by the inversion method is similar to SADCP upper 1000 dbar. The uncertainty of velocity observed by SADCP is about 10 cm/s. So we regard the error velocity from LADCP upper 1000 dbar as about 10 cm/s. Figure C.9.1 and C.9.2 show the results of the zonal velocity (eastward is positive) and the meridional velocity (northward is positive), respectively. The major currents in the western Pacific such as the Kuroshio (34°N to 32°N), the Equatorial Under Current (EQ to 3°N), and New Guinea Coastal Under Current (around 2°S) appeared in the figures. Figure C.9.3 shows error velocity estimated by the inversion method. The error velocities are very small (less than 5 cm/s) upper 1000 dbar and adjacent to the bottom from Stn.1 to Stn.42. After Stn.43, the error velocity below 1000 dbar become larger and exceed 50 cm/s at maximum. This is because the echo intensity of beam 4 got weak down after Stn.43.

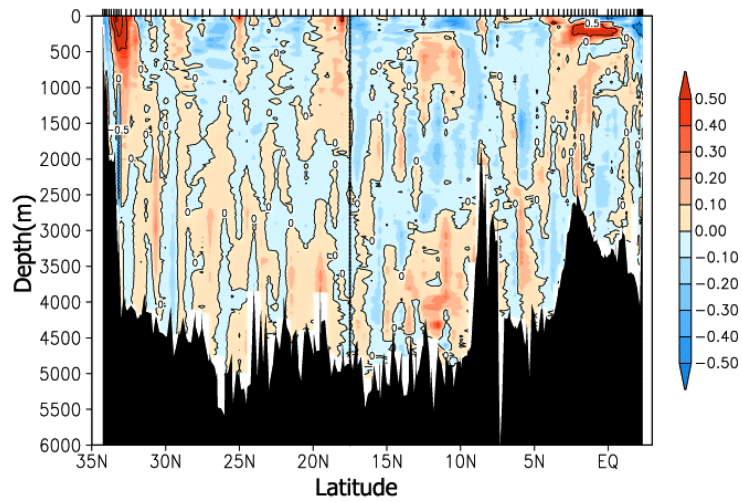


Figure C.9.1. The cross-section of zonal velocity (m/s, eastward is positive). Black line shows the Stn.43. The data south of the Stn.43 is doubtful due to malfunction of the instrument.

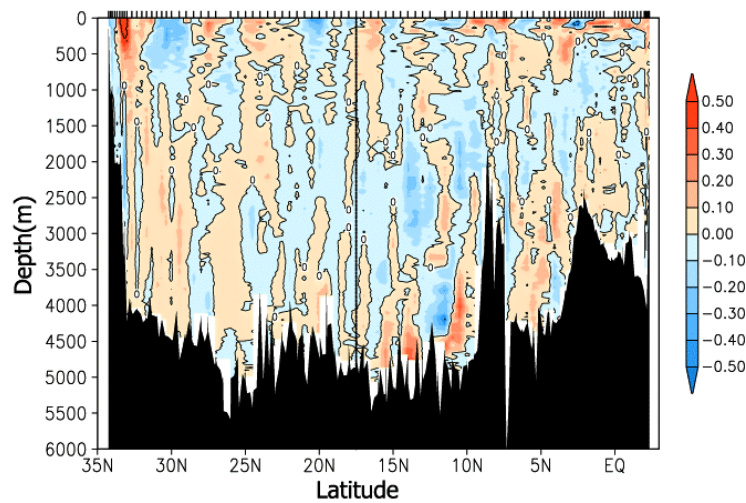


Figure C.9.2 The cross-section of meridional velocity (m/s, northward is positive). Black line shows the Stn.43. Note that southern of Stn.43 is doubtful.

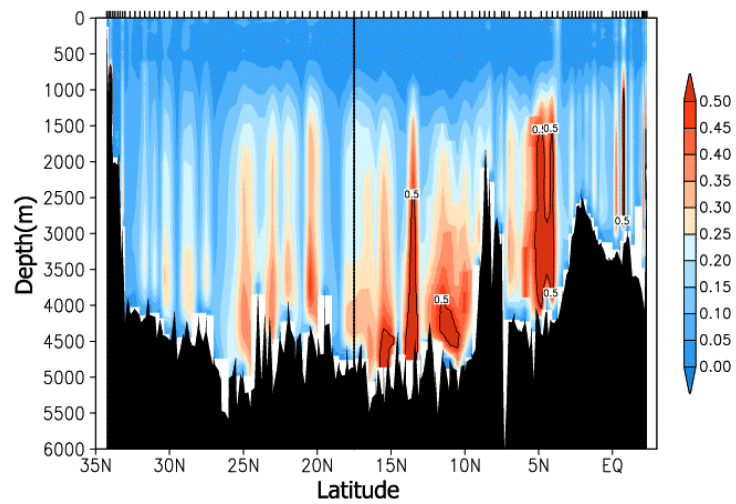


Figure C.9.3. Cross-section of error velocity (m/s) estimated by the inversion method. Black line shows the Stn.43. Note that southern of Stn.43 is doubtful.

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CCHDO DATA PROCESSING NOTES

Date	Contact	Data Type	Event	Summary
2010-12-27	<i>Nakano, Toshiya</i>	CTDO2	Submitted	Preliminary
	I send the preliminary CTDO2 dataset and document of RF10-05 cruise (WHP-P9 revisit).			
2011-02-02	<i>Berys, Carolina</i>	CTD02/Report	Website Update	Available under 'Updates'
	File 20101228_WHP-P9_revisit_ct1_doc.zip containing CTD data and Cruise Report submitted by Toshiya Nakano on 2010-12-27, available under 'Files as received', unprocessed by CCHDO.			
2011-03-14	<i>Diggs, Steve</i>	CTD/CTDO2	Update needed	CTD/Format
	CTD files as received need only a few modifications: - TIM -> TIME - 49UP20100706 -> EXPOCODE = 49UP20100706 - END_DATA at the end of each file Matt Shen and I will make the corrections and place the data (and documentation) online			
2011-08-17	<i>Shen, Matthew</i>	CTD	Website Update	Corrected Exchange and new NetCDF files online
	I made the following updates to the CTD files for http://cchdo.ucsd.edu/cruise/49UP20100706 : Exchange CTD * Corrected file format _ * TIM -> TIME _ * 49UP20100706 -> EXPOCODE = 49UP20100706 _ * added END_DATA NetCDF CTD * Generated from Exchange CTD			
2012-02-21	<i>Nakano, Toshiya</i>	CTD/BTL/SUM	Submitted	to go online